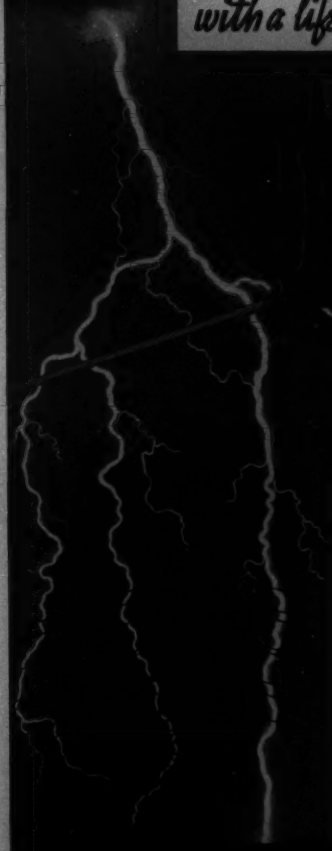
Electrical Engineering

April
1941

AIEE North Eastern District Meeting, Rochester, N.Y., April 30 – May 2

COPPERWELD OVERHEAD GROUND WIRE

with a life as long as the conductors it protects



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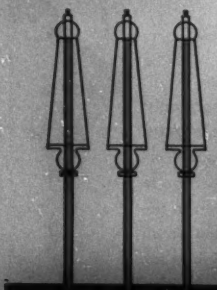
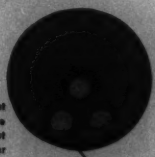


Trifurcating semi-stop joint (may be placed in manhole if desired) for bringing out single phase leads near base of terminals and isolating terminal section from main transmission line.



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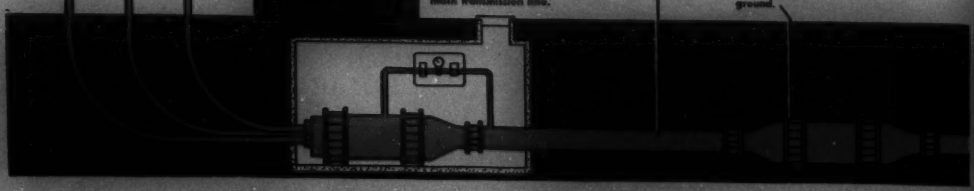

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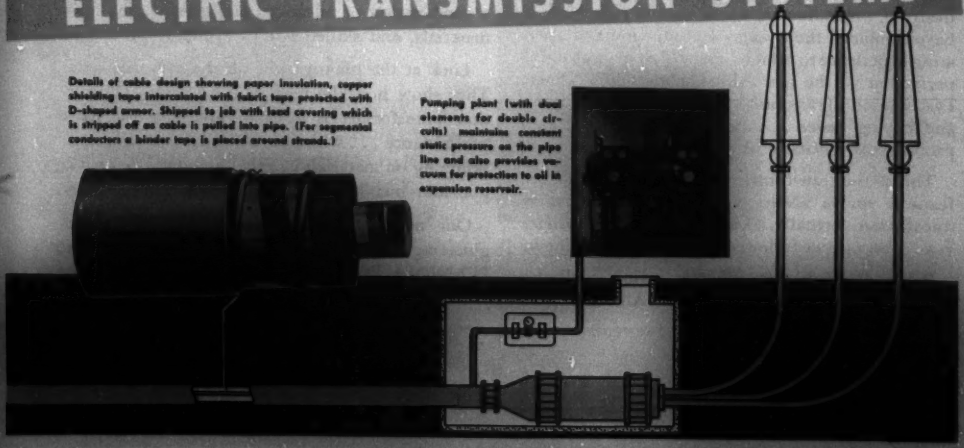

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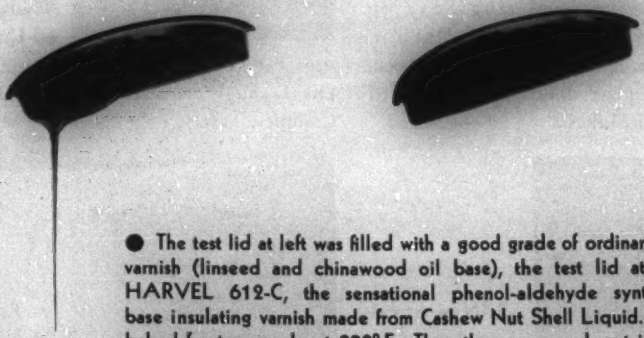

● The test lid at left was filled with a good grade of ordinary insulating varnish (linseed and chinawood oil base), the test lid at right with HARVEL 612-C, the sensational phenol-aldehyde synthetic resin base insulating varnish made from Cashew Nut Shell Liquid. Both were baked for two weeks at 220° F. Then they were each cut in half—and look at what happened!

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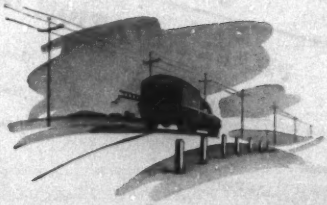

If you're one of the engineers who has taken it for granted that there'd always be a certain amount of trouble with transmission line and station insulators, you owe it to yourself to investigate the proved operating advantages of Lapp Line Post and Station Post insulators.

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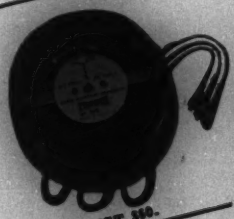

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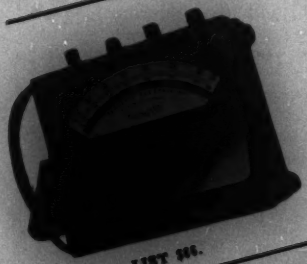

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Electrical Engineering

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for April 1941—

The Cover: Magnolia trees in bloom in the center of a parkway in Rochester, N. Y., site of the AIEE North Eastern District meeting April 30–May 2, 1941

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¶ Correspondence is invited on all controversial matters.

High Lights • •

Motion-Picture Technology. Gross box-office receipts of the motion-picture industry, one of the largest industries in the United States, totals more than $1,000,000,000 annually. Weekly attendance at the 18,000 theaters throughout the country totals some 85,000,000. Many technical and engineering problems are involved in the production of the 600 to 800 feature pictures now being filmed annually (*pages 168–72*).

Employment Dynamics. "Surveying industrial history, one detects certain trends suggestive of saturation with its inevitable bearing upon the employment problem," says a prominent AIEE member in speculations on this subject. He foresees the possibility of an increasing proportion of the people living in semirural communities where "while they might have their hand at the lathe or bench, would have both feet on the ground" (*pages 151–6*).

Speed Governors for Large Systems. The development of large interconnected power systems has created increasingly rigorous operating requirements; in spite of supplementary controls, the speed governors of the prime movers constitute the backbone of system control. Conclusions have been reached regarding performance characteristics of prime-mover governors for the larger systems (*Transactions pages 147–51*).

Finding Initial Derivatives of Transients. A new and simple method has been developed by which the initial derivatives can be found for an initially relaxed system of transients by a manipulation of the final differential equation itself; solution for a nonrelaxed system can be found by superposition or by means of a systematic change in the original differential equations (*Transactions pages 178–81*).

Rating Welding Machinery. A method of rating arc-welding generators and transformers has been proposed which includes, in addition to a current rating indicative of short-time welding capacity, a service-factor rating indicative of the continuous current-carrying capacity of the apparatus, as limited by thermal considerations (*Transactions pages 137–41*).

Electron Microscope for Laboratories. Improvements in the electron microscope (*EE, Nov. '40, p. 441*) have resulted in an instrument which is self-contained, occupies a relatively small amount of space and has an improved magnetic objective lens which increases its resolving power (*Transactions pages 157–62*).

Short-Circuit Oscillograms. Methods of analyzing short-circuit oscillograms of synchronous machines in accordance with the two-reaction theory have been developed and are compared with the more usual methods of analysis based on theories of symmetrical components (*Transactions pages 151–3*).

Stability of Power Systems. Studies have been made of system and apparatus performance during the period between the time allotted for the functioning of the high-speed relay protection and the point at which the system becomes so unstable that a major shutdown occurs (*Transactions pages 168–73*).

Operation of the Varioplex. A new method of telegraphic operation provides to each two stations connected by it an ever-ready two-way channel, which has a band-width of zero when idle and of variable dimension when busy; it is being adapted through telemeter service to use of private subscribers (*Transactions pages 181–4*).

Reducing Rectifier Corrosion. Chemical treatment with sodium chromate of the water used to cool steel-tank power rectifiers has been found to give excellent results in preventing corrosion from limiting the effective life of rectifiers of this type (*Transactions pages 173–8*).

Distributing Power to Industrial Plants. The secondary network system of distribution, such as is used in metropolitan areas, has been applied to industrial plants, and found to possess advantages of economy, flexibility, and reliability, over the commonly used radial type of distribution system (*Transactions pages 154–6*).

Upper-Air Weather Observations. Radio sondes, balloon-carried measuring devices which translate variations in meteorological conditions into corresponding radio signals, are being used to secure observations from the upper air; their use is also being extended to isolated locations (*pages 163–7*).

Arc Extinction in Flowing Fluids. Evidence has been assembled in favor of the theory of "diffusion" as contrasted with that of "displacement" to account for the effect of the circumambient fluid upon the circuit-interrupting ability of an arc (*Transactions pages 162–7*).

Design of Program Networks. The ways in which the various requirements of radio-broadcasting have influenced the engineering development of the networks have been reviewed and factors affecting further development surveyed (*Transactions pages 142–7*).

Airdrome and Aircraft Lighting. Paralleling the rapid strides made by the aircraft industry in recent years and in the facilities provided at airdromes, have been advances in the lighting art to meet the special needs of aircraft and to aid in night flight (*pages 157–62*).

Training Engineers for Defense. The role of the engineering colleges in meeting the need for engineers in the Army, Navy, and defense industries is discussed in relation to the Government program of vocational training below college grade (*pages 173–4*).

Corrections. On page 114 of the March 1941 TRANSACTIONS section of ELECTRICAL ENGINEERING, in the paper "The Electric Strength of Air at High Pressure—II" by H. H. Skilling and W. C. Brenner, the illustration listed as figure 3 should be figure 4, and the one listed as figure 4 should be figure 3. On page 507 of the December 1940 issue of ELECTRICAL ENGINEERING, in the article "Nomography for the Electrical Engineer" by Guido Ferrara, each of the values in the "L" scale of figure 6 should be ten times that shown in the figure.

Coming Soon. Among special articles and technical papers currently in preparation for early publication are: an article depicting the effects of complacency in confusion by Robert E. Doherty (F'39); an article on the measurement of cloud heights by M. K. Laufer and L. W. Foskett; an article on application of electric power in aircraft by T. B. Holliday; an article discussing static electricity in rubber-tired vehicles by Robin Beach (F'35); an article describing the new types of building wires recognized by the 1940 National Electrical Code and outlining their significance to the electrical engineer by M. M. Brandon (M'34); a report on factory wiring for resistance welders, part of the report of the subcommittee on power supply for welding operations of the AIEE committee on electric welding; a paper on modern relaying for a-c secondary network systems by D. L. Beeman (A'31); a paper embodying a new principle of cable design by W. A. Del Mar (F'20); a paper on the protective link, a new circuit-interrupting device, by J. K. Hodnette (M'30) and M. G. Leonard (A'34); a paper on an improved polyphase directional relay by B. V. Hoard (M'36); a paper on the development of the glow-switch by R. F. Hays (A'36); a paper on positive and negative damping in synchronous machines by M. M. Liwschitz (M'39); a paper describing a vertical flow outdoor compressed air breaker by L. R. Ludwig (A'28) and B. P. Baker (A'38); a paper on a conserved pressure air-blast circuit breaker for high-voltage service by W. R. Rankin and R. M. Bennett (A'37); a paper describing five years' experience with ultrahigh-speed reclosing of high-voltage transmission lines by Philip Sporn (F'30) and C. A. Muller (M'36); a paper on high potential testing equipment for quantity production by C. M. Summers (M'39); a paper on variations of atmospheric temperature with altitude in the United States by H. W. Tenney (M'36); a paper on methods of system control in a large interconnection by Earle Wild (M'36); and a paper on the control of switching surge voltages produced by the current-limiting power fuse by E. A. Williams, Jr. (A'37) and C. L. Schuck (A'39).

Subscriptions—$12 per year to United States, Mexico, Cuba, Porto Rico, Hawaii, Philippine Islands, Central and South America, Haiti, Spain, Spanish Colonies; $13 to Canada; $14 elsewhere. Single copy $1.50. ¶Address changes must be received by the 15th of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge. ¶ELECTRICAL ENGINEERING is indexed annually by the Institute, weekly and monthly by *Engineering Index*, and monthly by *Industrial Arts Index*; abstracted monthly by *Science Abstracts* (London). Copyright 1941 by the American Institute of Electrical Engineers. Printed in the United States of America.
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Speculations Concerning Employment Dynamics

ROBERT W. KING
MEMBER AIEE

ENGINEERS are well schooled in the distinction between statics and dynamics. Hence a title has been chosen which suggests that the problem of maintaining employment is dynamic in character and involves the discovery of reactions which can be used to balance certain varying social forces.

The cycle of availability of work followed by scarcity has doubtless operated as unremittingly down through the ages as peace and war. And at long last, as in the case of war, we are beginning to realize that any considerable and sustained degree of unemployment presents a serious threat to the foundations of liberal society. The discovery of adroit means to damp employment oscillations is a first-line problem in every industrial nation. In fact, there are cogent reasons for believing that the threat of war is itself inherent in insecurity of employment. Peace both within and without are therefore mutually at issue.

At the outset of this analysis, it may be well to note that the problem is not simplified by the fact that human beings are so constituted as to let the profit in hand outweigh considerations of ultimate good. Because of this characteristic, society frequently finds itself seriously out of phase with the law of diminishing returns, and troubles become extreme before the need for adjustment or correction is recognized, or at least admitted.

This discussion, based upon an address delivered before Professor Philip Cabot's Business Men's Group at the Harvard Business School, is presented here for the purpose of stimulating thought among AIEE members on a problem of importance to all engineers; the "Letters to the Editor" columns are open to contributions on this current topic.

One permanent cure for unemployment was suggested in an inimitable verse which appeared in *Punch* just prior to the outbreak of the war in Europe—and no apology is made for reproducing it here.

'ONLY A SUGGESTION'

By Evoe

I thought as I sat by the shore of the sea
What a wonderful, beautiful thing it would be
If the Briton, the Teuton, the Gaul and the Slav
Should take all the guns and the tanks that they have
And sink them out there in the infinite main,
And then begin building them over again.
For no one, you know, is desirous to fight,
They are only protecting the Truth and the Right,
And nothing but armaments endlessly made
Can stop Unemployment and benefit Trade,
And the Heart of a Nation as never before
Is united when making Munitions of War.
How happy the state of the world when it finds,
What is simple to all mathematical minds,
That you cannot go on making gun after gun,
Because there is nowhere to put them when done,
And the largest of factories, even the Banks,
Would refuse in the end to find storage for tanks.

But a little more trust between nations, I think,
Would allow them to meet every August and sink
In a suitable place they could easily settle
Enormous supplies of explosives and metal,
And a cup would be given—the winner to count
As the one that got rid of the largest amount,
And could soonest return to the Blessings of Peace
Which are instantly doomed should Rearmament cease.

I thought as I sat by the shore of the sea
What a wonderful, beautiful thing this would be
For Commerce and Culture, and Friendship and Cash;
And the children, no doubt, would be pleased by the splash.

Unfortunately for the world, this rhymed proposal came too late to save Europe.

A SIMPLE PROBLEM OF UNEMPLOYMENT

An imaginary situation will serve as a useful beginning. No apology is offered for its simplicity, save the parenthetical remark that science usually begins with the simple and only as it masters elementary cases does it attempt those that are more involved.

Let us suppose that there was once a society which lived comfortably off the land. Their pursuits were wholly agricultural, aside from the fact that they had mastered the art of making houses for themselves. They had, to be sure, their abundant years and their scarce ones, but these were made not too troublesome by a system of carry-overs. Into this simple society we will suppose two inventions to have been introduced at about the same time. One of these involved a farm process which reduced the man-hours necessary to insure an adequate food supply. The other invention took the form of an object of household utility, let us say the clock.

The clock proved to be not only useful but an object of novelty, so that every household wanted at least one. Fortunately the agricultural invention which resulted in an economy of labor on the farm provided a labor surplus which, in turn, could devote itself to making clocks. Those individuals who were no longer essential on the farms succeeded, in a little while, in acquiring the mechanical dexterity which the nascent horological trade required. Thus, a satisfactory labor balance was established.

But only temporarily, for the clock proved to be inherently a long-lived contrivance. Once a household had acquired its timepieces, its needs were satisfied for an indefinite future. Those who had been displaced or had

ROBERT W. KING is assistant vice-president of American Telephone and Telegraph Company, New York, N. Y.

allowed themselves to be displaced from agriculture and who had initiated the clock trade, discovered after the lapse of time that their business was languishing. To the extent that the clockmakers had equipped themselves with little shops at home where they lived as members of a family group, no particular uncertainty resulted, for when trade was slack, they could fall back upon their families for support. But we must imagine that there were more enterprising fabricators of clocks who, realizing the economies inherent in division of labor, set up small factories in which they employed various of their neighbors. With these neighbors all went well for a time, but when clock saturation arose, they were destined to live either upon their savings or upon charity.

In spite of its extreme simplicity, this clock parable presents a challenge. The problem before this simple society is to restore the economic value of the clockmaker's time. Viewing their predicament from our own advanced position, we are prepared to make several suggestions. Some of us, being internationally minded, would advise the hypothetical society to cast about for another social group or nation that needed clocks and that could export some other commodity or gold in exchange. Others, discerning a fringe of marginal farmers who are less abundantly provided with clocks than the rest, might advance arguments in favor of technological improvements to the end that cheaper clocks could be placed upon the domestic market. Still others would see an obvious line of escape in further invention, resulting in some new device to replace the clock as an article of trade. And finally there would assuredly be a suggestion that hours of labor must be rationed so that everyone could have some.

Each suggestion has merit and offers some relief. The difficulty arises when we inquire as to how much relief each can or should be called upon to supply. And of course there is the additional problem of determining how each ameliorative process should be made to vary as a function of time.

A POSSIBLE LIMIT TO MATERIAL WEALTH

It is with the second and third processes and their time variations that technology is particularly concerned. As a beginning let us draw a picture of our own future untrammeled by any inhibitions. Let us vision an era in which the most modest family income will encompass not only a comfortable house and garden, but a small summer cottage or hunting lodge, at least one motor car, a cabin cruiser or such other nautical equipment as meets the family taste—in a word, a physical plant which on the basis of present-day values might represent an outlay in the neighborhood of $10,000. We need not, for the moment, pause to consider how it became possible for families, generally, to acquire so extensive a menage. Our interest is directed to the consequences, not the causes, of the situation. We are struck at once with the heavy maintenance problem that would face the nation. Taking $10,000 per family purely as a convenient average for purposes of argument, and remembering that there are approximately 32,000,000 families in the United States, the resultant physical plant would be worth 320×10^9. In contrast to this sum, the manually created physical assets of today (there are four principal categories excluding land and natural resources) have the following approximate values:

Buildings and other improvements on land	64×10^9
Structures of public utilities	46
Factories and other production assets	24
Durable family possessions, household furnishings, motor cars, etc.	25

Now assuming rates of maintenance and depreciation on these items of 3 per cent, 5 per cent, 15 per cent, and 10 per cent respectively—figures which are probably conservative—one discovers that effort equivalent to about $\$10\times10^9$ per year is required to maintain our *status quo*.

This calculation gives a ready index of the consequences of multiplying the average family holdings by any assumed factor. Even such an increase as a restrained imagination might fancy would, we see, involve maintenance and replacement expenses greater than the present entire national income. So, much as in the mind's eye we would like to multiply our physical possessions, we sense that there must exist some limit beyond which we cannot go. The vision of American industry, running at ever higher speed and turning out a greater profusion of gadgets and paraphernalia of all descriptions, appears to have at best a somewhat unsubstantial foundation. At some stage perhaps near, perhaps remote, industrial expansion threatens to bring us into approximate coincidence with a kind of ceiling which owes its existence in part to the inescapable character of maintenance and depreciation. Since the situation is not static, because the rates which we must set for maintenance and depreciation are subject to the attack of science, it is necessary to envisage a sort of race between the activities of science which are multiplying material aids, and those which are endowing them with longer life. Nevertheless, as we acquire material wealth, we must expect to have brought home to us more and more that we are in a situation similar to that of Alice and the White Queen who had to run faster and faster to stay where they were.

TECHNOLOGY ASSOCIATED WITH SWINGS OF INCREASING VIOLENCE

In passing, it will be as well to note that one of the most direct consequences of the maintenance problem has a serious employment aspect. Much of the nation's expenditure for maintenance is obviously for consumer goods, and one form which enforced economy invariably takes is that of curtailed care to existing structures. Individuals and corporations alike are inclined to forego all but urgent upkeep and repairs during times of economic stringency. This fact may well account in part for the severity of the latest depression and have a bearing on the depth and duration of future depressions; for obviously the larger the labor requirements that enter into annual maintenance the larger is the potential element of unemployment if for any reason maintenance is postponed. It is but fair to note, however, that such postponement should in the normal course of events bring about an equally sudden demand for labor, once pessimism has given way to optimism.

Nevertheless, unless we can introduce counteractive measures, the situation thus created is one conducive to oscillations of increasing violence.*

The phenomenon just mentioned has frequently been noted and is, indeed, one of minor significance in the long term view of technology as it affects employment. So let us turn to consider the partition of social effort between activities of production and activities of distribution. Examination of this partition shows evidence of a marked evolutionary trend over the years. Although the callings of the jobber and the retail merchant—even the advertising man—trace back to earliest historical times, they once played a less conspicuous role in the sum total of society's activities than they do today. Sales stimulation has assumed steadily increasing proportions and importance. The same applies to all other agencies of distribution, such as transportation and communication, and also to the professions and the service agencies. Indeed, today the trend has carried us so far that, as a recent survey by the Twentieth Century Fund shows, out of every consumer dollar, about 59 cents go to defray the expenses of distribution and service while only 41 cents go to the agencies of production.

INCREASING SALES RESISTANCE

Such figures are challenging. They suggest a well-advanced stage of the ceaseless and age-old struggle for the consumer's dollar. There may never have been a time when consumer goods, in effect, sold themselves; but with the growth of modern industry and mass-production, a need has arisen to bestow increased effort upon techniques for stimulating the distribution of consumer goods; so much so that, whereas in 1870 the forces in production and sales stood as 3:1, the ratio in 1900 had become 2:1, and now stands at 1:1.† In other words, industrial maturity of the nation shows up indirectly in an increasingly keen competition for the still unpreempted sector of public appetite—a sector which, as we shall see later, may be growing smaller as the average consumer holdings of material possessions expand.

Such an interplay of forces, while more deep-seated, may be likened to the engineer's effort to attain what he calls an "economic balance." Take, for example, the competition which leads to the erection of a filling station on each of the four corners of a single busy crossing. Such construction must mean that a readier opportunity of employment is to be found in the intensive development of filling stations than can be created by increasing investment in productive capacity. But so far as the consumer of oil products is concerned, would he not be better off if the number of filling stations throughout the land were reduced to one-half or one-third their present number and the resultant savings handed on in the form of a lower retail price? However, the struggle for employment—the modern form of the struggle for existence—appears to preclude this otherwise logical suggestion. Taking all present factors into account, there is perhaps no better way that many persons can impart an economic value to their time than by manning unnecessary, but not unpatronized, filling stations.

Thus, while it is easy to declare that the nation is supporting many more distributive outlets than need be, and that if this surplus were done away with, prices to the consumer could be lowered, such a proposal ignores the fundamental fact that there is no present possibility of offering other employment to those displaced by this measure toward economy; and until other avenues of employment appear—and these, to effect a realignment must, of course, appear in production—our preponderant distributive forces must, perforce, remain preponderant.

This argument leads us to examine anew the common supposition that those technological contributions which have been labor-saving have, in general, proved to be job-creating, and that among the resultant train of events a shortened work-day and increased wages are conspicuous. The implication is not uncommon that technology has *permitted* the shorter work-day. Yet, if this be so, how do we explain what appears to be the ever-present threat of overproduction? Let us imagine the consequences of suddenly lengthening the hours of labor. Thus, had production of consumer goods gone forward in 1928 or 1929 upon the basis of a 12-hour day, one fears that the consequence would have been a glut in virtually all markets, irrespective of the fact that the income available to purchase these goods could have increased proportionately. It might be more accurate, therefore, to say that technology has necessitated the shorter workday. This conclusion is deducible likewise from the lengthening interval of schooling for youth and from the lowered age of retirement. The presumption, therefore, is that given our present industrial setup, a sort of incipient overproduction of many—perhaps, indeed, of most—kinds of commodities we have *devised* and are *equipped to make* hovers over our economy.

Another way of stating the inference is that industry, in its present limited state of diversification, might encounter a serious number of inelastic markets were production to be stepped up very much. And still another is that with the development of labor-saving schemes, the shorter work-day has, in large part, been an unconscious adaptation on the part of industrial society to certain little-remarked inflexibilities. Hence, while it is manifestly premature to venture any dogmatic assertion, we might be well advised to harbor a suspicion that the mechanism which industrial society depends upon to maintain adequate—even expanding—employment is, in fact, near a sort of overload point.

OTHER EVIDENCE OF THE LIMITS OF ECONOMIC EXPANSION

We pass now to a third little-discussed long-term phenomenon which seems to possess fundamental significance. It is, perhaps, the most enigmatic of all. To put the matter as a question, has any industrial nation unless possessed of a rapidly growing population (and this may be interpreted as equivalent for purposes of the present

*Recent evidence of a nationwide curtailment of maintenance and replacement is found in Department of Commerce data. If these may be taken at face value, they show a serious erosion of national wealth. For the five years from 1930 to 1935, a net loss is reported each year; the largest was $9,000,000,000 for 1932, the smallest was $1,500,000,000 in 1934, with a five-year total of $26,000,000,000.

†See the Industrial Conference Board's "Enterprise and Social Progress," p. 48.

discussion to an expanding geographical frontier) been able long to maintain prosperity on a basis other than a net export of manufactured goods? England, for a period of a century or more, built up a commanding position in world trade through the development of foreign markets for its manufactures; but when these foreign markets began to dwindle, as they did with the initiation of colonial and other local industries, England's prosperity went into a long and refractory decline. Likewise Germany, which before the World War was a prosperous nation with ample foreign markets for its excess industrial production, largely lost those markets during the War. With the conclusion of peace, she found herself unable to regain any semblance of her earlier prosperity—and this in spite of the fact that the needs of her own people for manufactured goods were never more desperate, and in spite of the fact that considerable foreign capital was loaned to initiate renewed manufacturing activity. The recovery of lost foreign markets proved a slow and laborious process, with the result that her industrial machine lay strangely impotent in the face of pressing domestic demands.

The evidence from Nazi Germany is no more reassuring, for prior to the advent of the war, the industrial machine was satisfied by an inordinate emphasis upon the manufacture of armaments—an observation which prompts the question as to whether it might not have been about as well satisfied by the enforced manufacture and alms-like distribution of consumer goods, and with far more welcome consequences both at home and throughout the world.

The case of the United States to date differs from that of either England, Japan, or Germany, for we have had, until very recently, geographical frontiers or the equivalent in undeveloped natural resources which have induced a rapid growth of population with expanding markets for manufactures, markets which, in certain respects, are equivalent to those on foreign soil. Our population growth, however, is now leveling off and the question arises as to whether in the decades to come, the maintenance of youthfulness in our industrial machine may not prove as much of an enigma as it appears to have done in older countries.

ARE THERE UNDEVELOPED DOMESTIC MARKETS?

But what of the "have-nots" and the potential market which they offer? The existence of these "have-not" groups, with the apparent promise of wider home markets which it implies negatives in some minds any belief that national industrial output should be regarded as in an incipient state of leveling off. Consideration of this problem can perhaps best be initiated by discussing a specific illustration.

A recent report of the National Resources Commission which concerns the northern portions of Michigan, Wisconsin, and Minnesota, offers a convenient approach. The report points out, in effect, that so far as concerns most of the $1^1/_2$ million people who live there, there is little that they can make, or grow, that the rest of the country particularly wants. A generation or so ago the people there were confident and optimistic. They found forests, fish and mines, and some good farm land. So, as becomes a self-respecting community, they built schools and roads, and went in debt to do so. First the forests disappeared, then the fish, and finally machine methods of mining largely replaced hand labor.

This portrays one socially important type of the "have-not" problem. The $1^1/_2$ million people who inhabit the region in question lack many things that those more fortunately situated geographically take for granted—things which they very much want, and for which they would be willing to work, but for which they cannot work under present conditions. One direct plan for bettering their lot would call for the erection of factories and mills in their own territory, for which they, themselves, could supply the labor. In this way, it would be possible for them to satisfy most of their present wants; but what then happens to the rest of the country, where factories and mills for making these very commodities already exist and where ample labor is available to turn out all that the entire nation needs, and frequently more that must seek foreign markets?

As matters stand in the United States today, the dispersion of industries from more industrialized regions—and among these our larger cities are perhaps the most conspicuous—to less developed areas is more than an academic matter. Prior to the incidence of the depression, a migration from northern to southern states had begun, and appears as yet to be incomplete. It is nominally explained as having taken place in response to the lower wage levels of the southern states; but this is merely another way of saying that prior to industrialization the average worker's time is not so productive, and therefore not worth so much to society. It is also tantamount to saying that the dwellers of the south, while lacking commodities being produced in the mills of more industrialized areas, had not the wherewithal to purchase them.

What, then, are we to conclude? We see new industrial regions springing up; that is, we see industry disseminating itself to sections of the population to whom it has heretofore been unable to sell its products. We see many older industrial areas undergo partial eclipse as a result of this migration, with consequent jeopardy to workers' security and property values. We see this change come about in response to certain developments of present-day technology. Is the transformation a wise one? It may mean, for instance, that the areas now launching themselves upon the road to industrialization are setting out to traverse a route which, in many respects, is like that traversed by the areas first industrialized—a route, in other words, about which we are seeking to determine whether it leads to an *impasse*, or whether after a little rough going it will open out into a sort of promised land. Thus the current industrial expansion of the southern states and other less developed areas, may turn out to be a case of rectifying one mistake by making another of similar kind. It reminds one of the limerick concerning the mouse in the stew:

> A gentleman dining at Crewe
> Found quite a large mouse in his stew.
> Said the waiter, "Don't shout
> And wave it about
> Or the rest will be wanting them too."

Be this as it may, there nevertheless is impressive strength in the argument that the process of supplying manufactured goods in appropriate quantity to those whom we now class as the "have-nots," appears to offer no adequate outlet for the nation's present industrial mechanism as a whole. And, especially, to the extent that it is necessary for the "have-nots" to equip themselves through the agency of their own labor, albeit with borrowed money, their present potential consuming power—not *purchasing* power, for of this they have little—appears an industrial liability, not an industrial asset.

It is interesting to restate this argument by comparing such a depressed area to a small nation. The nation would, as economic history amply shows, follow just such a scheme, attracting in foreign capital to create the industries desired, and erecting tariff barriers if need be. Many would label this procedure an attempt at autarchy and proclaim that only through the free movement of goods across national boundaries can the world hope to maintain peace and prosperity. The procedure followed by the little nation does, however, help it for the time being irrespective of whether, in the long run, it may come to suffer from industrial indigestion in much the same way as the recent status of large nations suggests.

Without attempting to carry the argument through expanded stages, a procedure which, it seems likely, would weaken its suggestiveness without destroying its validity, the handwriting foretells a time when industry's market, by and large, will be predominantly a sort of local replacement market. In other words, the possibility of significant "exports" to less developed areas will play a diminishing part in the economy of any geographical district, and hence of a nation as a whole, if large like the United States.

Likewise, the other forces which are commonly regarded as working to lift the nation's industrial level—such other forces as science and invention—may, as has been noted, prove of uncertain value as agencies to bring about marked future expansion of employment.

THE ENGINEER'S SOCIAL OPPORTUNITY

This is a novel situation so far as the United States is concerned. With minor exceptions, American political philosophy has been guided by the vision of ever-expanding markets. Even in times of slack employment, a greater future has seemed to lie ahead, and to the nation as a whole there has come no intimation of an industrial ceiling. But surveying industrial history, one detects certain trends suggestive of saturation with its inevitable bearing upon the employment problem. Then too, as already noted, the course of industrial evolution has been such as to create employment conditions which can become markedly unstable. In a situation so complicated by imponderables, it is manifestly unwise to hasten to conclusions. Yet this is not the first time the engineer has been confronted with situations which are not reducible to exact control. With his factors of safety he manages to make allowance for his ignorance, and on the whole does so with satisfactory results. Granting that the analogy cannot be considered exact in all respects, it may not be amiss, however, to weigh the idea of social and economic factors of safety on a nationwide scale. Indeed, the use of factors of safety already extends farther than the limits of engineering. They are well known and, of course, highly developed in both banking and insurance, and their extreme serviceability in these quarters again speaks in favor of a wider application.

It is the precise manner of application which principally remains in doubt. However, in the modern state a factor of safety might well be directed at the inherently oscillatory character of many social and economic forces, and in particular at the disastrous consequences which so frequently attend these swings. The advances in technology, as thus far employed, have, we see, tended to enhance the oscillatory character until the present unimpeded surges are inimical to the maintenance of Social Solidarity. It is pertinent, therefore, to inquire whether present day technological knowledge might be so adopted as to promote less abrupt and less disruptive economic and political changes; in other words, whether a scheme of social security and social insurance can be woven deliberately into the technological fabric of the nation, not, as in recent legislation, superimposed upon it as a weight of taxation and something to be converted into a political football should occasion offer.

To mention parenthetically but a single gross defect in current social security legislation, there is the fact that while it provides a monetary compensation for loss of employment, it offers no substitute occupation but leaves the recipient in idleness. This can be considered tolerable only if no alternative security of subsistence which at the same time provides employment for the hands or mind or both can be devised.

Here the engineer might risk a suggestion. A fundamental social factor of safety must be concerned with the ready availability of food to every family. One promising approach may lie in a trend already in evidence, namely, the transfer of many factories and mills out of large cities, with the result that most bread winners, while they might have their hand at the lathe or bench, would have both feet upon the ground. Such relocation—taking place gradually, to be sure—might offer a variety of trades within relatively small compasses, and yet the land area available to each family would permit of subsistence. To make the most of such a change, the engineer should adopt a broader social outlook, for his would be the responsibility of molding many of technology's most important agencies to the needs of a vast rural rather than a highly concentrated population. It would introduce an enlarged element of social awareness and social responsibility into his problems. Conspicuous among the agencies which would have a fundamental role to fill are transportation, electric power transmission, and communication. When suitably developed and employed there seems little doubt that many, if not all, of the industrial and commercial advantages and educational and cultural amenities now found in dense urban communities could be retained by a dispersed population through the proper use of these basic auxiliaries. For those individuals constitutionally wedded to urban life there would still be

cities; but for another large contingent of erstwhile urban population there would arise a new-found security and freedom.

The fact that only about 20 per cent of the nation's labor is now employed in agriculture, shows the wide margin of the gainfully employed which, under such redistribution, would be available for manufacturing. And to bring industrial work into intimate contact with food supply should greatly simplify the nation's mechanism of life. The task, as we face it today, of maintaining a far-flung balance between large producing population groups, agricultural and industrial, in spite of certain operating economies which may reside therein, is so uncontrollable, and when out of control so disastrous, as to suggest a need of revision. This, indeed, may be one of the paramount lessons to be derived from the past ten years of uncertainty. By dispersion we would equip the industrial mechanism with a safety guard against the periodic spectacle of idle millions in the cities being fed from public funds, and of semi-idle millions in the country districts wanting the products of industry but lacking means either to make or buy them. At the same time, we would aid the farmers of low purchasing power by bringing a goodly portion of industry to them.* In a word, we would succeed in simplifying the geographical status of our division of labor with a resultant gain in stability. We would have traded a complicated and periodically unreliable mechanism for one which, while seeming in certain respects to revert to an earlier model, would be more rugged and better able to withstand the shocks of the road.

*The subsistence type of farmer would remain such, but by turning a part or all of his surplus time to account in a nearby mill or shop he could equip himself with a reasonable number of life's physical conveniences and comforts. As for the commercial farmer, he might enter the "extractive" field, and raise crops utilizable as raw materials.

Power Plant at the New Port of Buenos Aires, Argentina

SHOWN at the right is the power plant of the Compania Argentina de Electricidad located at the New Port of Buenos Aires. The plant was placed in operation early in 1929 with two General Electric turbine-generator units with steam reheating between the cylinders of high and low pressure. Today the plant, interior of which is shown below, has four units, and a fifth is being installed this year. The plant's output in 1940 was nearly 1,150,000,000 kilowatt-hours.

EACH of the turbine-generators, shown at left, is rated at 52,500 kw and 1,500 rpm; pressure 550 pounds per square inch, temperature 750 degrees Fahrenheit. The fifth unit will have a speed of 3,000 rpm. Only two of the present units have intermediary reheating of the steam. Pulverized coal has been the type of fuel chiefly used.

Airdrome and Aircraft Lighting

Although long strides have been made in recent years in the development of suitable equipment and methods of installation for the night lighting of airdromes, much remains to be done before airdrome lighting facilities can be considered ideal. The first of the following pair of articles describes lighting equipment now in use at the permanent airdromes of the United States Army Air Corps, and discusses the problem of distribution of electric energy for lighting. The second article describes the lighting equipment developed for special uses on Army aircraft.

Airdrome Lighting

WILBUR T. HARDING

FIFTEEN years ago, the equipment available for night lighting of permanent airdromes of the United States Army Air Corps was quite inadequate and the proper methods of installation were unknown. Today, although both of these deficiencies have been minimized, much is yet to be accomplished before airdrome lighting facilities reach the ultimate in performance.

Where possible, commercial equipment has been used. Due to the necessity for procurement by advertisement, detailed specifications had to be prepared to insure receipt of satisfactory articles. In such procurements, governmental engineers are handicapped more than engineers connected with private concerns who can select and procure their equipment where they desire.

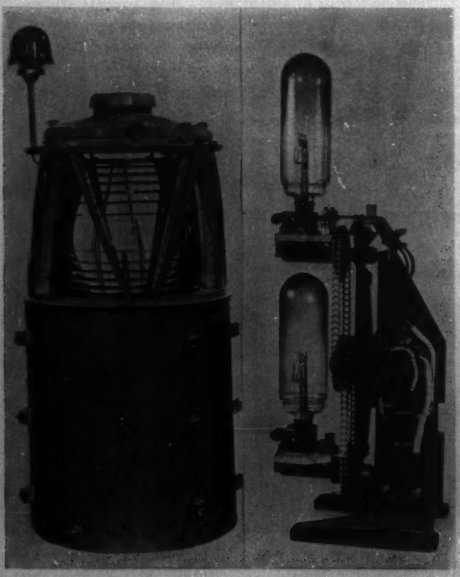

Figure 1. Lamp assembly, type D-2 beacon (left), and lamp changer (right), United States Army Air Corps

The beacon uses a 1,500-watt 32-volt lamp, and is equipped with the lamp changer shown at the right

Many items of equipment, however, had to be designed by the Air Corps or their development by commercial concerns encouraged. The procurement of equipment for a modern airdrome today involves the use of some 50 equipment specifications, all of which must be revised periodically.

Commercial designers of equipment often overlook entirely the problem of installation, or they attack it as an afterthought when the design is nearly completed. To overcome this defect, Air Corps specifications often departed materially from commercial standards, much to the consternation of some of the suppliers. The Air Corps at present has installations of night lighting equipment at approximately 40 fields. The personnel at these fields does not hesitate to point out unsatisfactory features, which are often used as a basis for specification revision or development of new equipment.

Airdrome lighting resolves itself into two major engineering problems. Of first importance is that of proper light distribution which is the concern of an illuminating engineer. The problems involved herein, however, are too lengthy for inclusion in this article, which is devoted primarily to a discussion of equipment used and the problem of electrical distribution.

EQUIPMENT

Beacon. The standard Air Corps beacon (figure 1) consists briefly of a Fresnel lens optic in which the lamp is moved periodically along the axis of symmetry.[1,2] The result is a radial beam of light that sweeps up and down through a vertical angle from 2 to 18 degrees above the horizontal. When viewed by a distant pilot, the beacon appears to flash normally 80 times a minute. The principal advantages of this beacon over the older rotating types are:

1. The beacon flashes normally 80 times per minute as compared with the 6 flashes produced by a rotating beacon.

Essential substance of a paper presented at the AIEE Middle Eastern District meeting, Cincinnati, Ohio, October 9–11, 1940.

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1. For numbered references see list at end of article.

Figure 2. Wind indicator, type B-5, Air Corps, is 36 feet long, tetrahedral in shape, and constructed of steel tubing covered with fabric. It is lighted by 35 ten-watt red and green lights along the edges

2. The signal within limits is independent of altitude, which allows a pilot to approach a field at a constant altitude. The conventional rotating beacon is inclined at a fixed angle above the horizon; the pilot often is above or below the center of the beam and misses the signal in bad weather.

Wind Indicator. The standard Air Corps wind indicator is shown by figure 2. Its position can be interpreted either by day or by night from the ground or from low altitudes. This indicator was developed by the Air Corps.

Outline Lights. The usable landing area generally is outlined by a system of obstacle and boundary lights. The former mark dangerous obstacles which must be avoided, and the latter denote the limits of the landing area. Boundary lights were originally of considerable value for fields where the entire area was used for landing purposes. For fields having hard-surfaced runways, however, their use is problematical and they may be eliminated ultimately.

Floodlights. Floodlights for illuminating the landing area can be classified readily into two general types:

1. One type covers a fairly large area upon which landings can be made in any direction. Such floodlights are applicable to fields that do not have runways, such as training fields or small privately operated fields. For such applications, there have been advanced many and different solutions. In general, for fields at which the wind conditions require approaches from all directions, three or four banks equally placed around the landing area, each with selective control and each covering a sector not exceeding 90 degrees, has been found to be the most acceptable arrangement (figure 3).

2. The second type of floodlight is applicable to fields that have hard-surfaced runways at which it is desirable to restrict the floodlighting to the runway surfaces. The bridge type of installation with drum floodlights shown by figure 3 can best be utilized for this purpose. The standard practice of the Air Corps at present is to place such an installation at the approach end of the runway approximately 300 feet to the right and to utilize four spread lenses. An 80-degree lens is used to cover the runway closest to the floodlights, then 30-degree, 10-degree, and plain lenses to cover successive portions.

There is a tendency at present toward the elimination of floodlights at fields that have hard-surfaced runways and adequate runway contact lights. Many pilots prefer

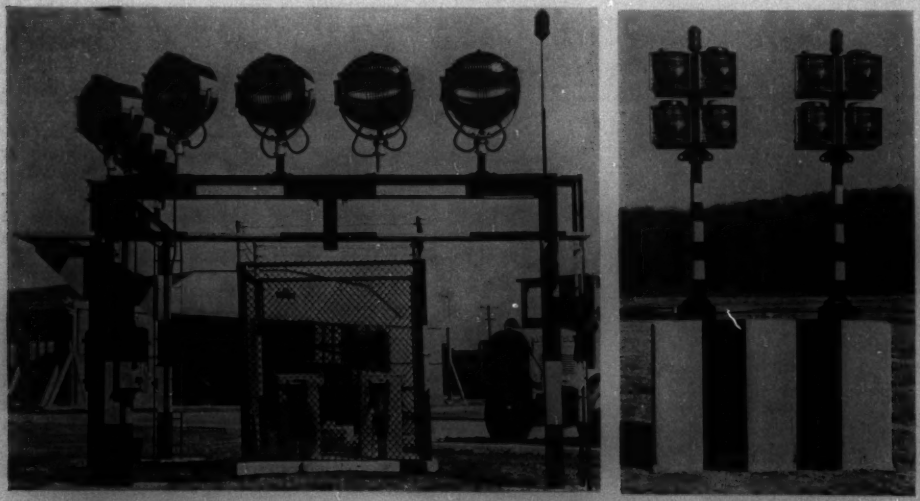

Figure 3. Floodlight installations at Kelly Field, Texas (left) and Bolling Field, Washington, D. C. (right)

In the typical installation upon a floodlight bridge shown at the left each bridge is equipped with four drum-type floodlights, each of which has a 30-degree lens and a 3,000-watt 32-volt lamp. This arrangement will cover a sector 90 degrees by 2,500 feet. For additional illumination, a second bank covering the same area may be added. A sector of the same size is covered with the use of only half as much wattage in the installation shown at the right, which is applicable to fields that are quite level. Each floodlight uses a 1,500-watt 32-volt lamp. It is less applicable to fields with irregular contours or those requiring a sector of less than 90 degrees

to land without floodlights, depending upon aircraft landing lights if additional lighting is necessary. The latter, however, are unnecessary for a trained pilot if the ground contact lights are adequate.

Runway or Contact Lights. As indicated, contact lights, if adequate, form a major part of an airdrome lighting system. These lights are placed along hard-surfaced runways at regular spacings and have a specialized distribution which concentrates the light signal in the angles along which a pilot normally approaches for a landing. These lights (figure 4) are essentially marker lights denoting the position of the runway surface.

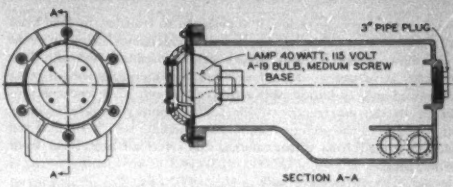

Figure 4. Lamp assembly, runway marker, type B-2

Approach Lights. Under adverse weather conditions during which aircraft may be guided toward the approach to the landing runway by radio aids, it is generally recognized to be extremely desirable to complete the landing operation by observing ground lights in lieu of making a complete blind landing. Toward this end the Civil Aeronautics Authority and Army Air Corps for several years have been attempting to devise and develop equipment. At the present time, a system of lights 1,500 to 3,000 feet long which will mark an approach path leading into the runway is being considered. It is the intent of the developments under way to have the approach lights serve as the first ground aid which, in turn, will lead into the contact-light system which will be used for completion of the landing maneuver.

Future Developments. The future of airdrome lighting depends upon the successful development of approach and contact lights which will permit operations as just described. When this is accomplished, boundary and floodlights are likely to be discarded except for training fields.

ELECTRICAL CIRCUITS

Series circuits are used for outline-light, contact-light, and approach-light systems. With these circuits, series multiple transformers are used for the following reasons:

1. In case of collision, the high-voltage series circuits are usually undisturbed.

2. Obstacle lights may be installed upon buildings without danger due to high voltage.

3. Magnetic coupling between the series circuit and lamp reduces the possibility of short-circuiting a circuit or part thereof if water grounds one or more lights. This is especially applicable for contact lights.

A typical installation of a subway type of series multiple transformer in the base of a contact light is shown by figure 5. This installation is designed to seal the cable entrance yet allow quick replacement of the transformer if necessary.

For floodlights it has been the practice to supply a 2,300-volt primary feeder from center of distribution to floodlight. At the floodlight a 2,300/32-volt transformer with taps to compensate for line drop is used. Switching is accomplished at center of distribution. Controls of the various circuits are centralized in a control tower where radio and light aids are under the jurisdiction of trained operators.

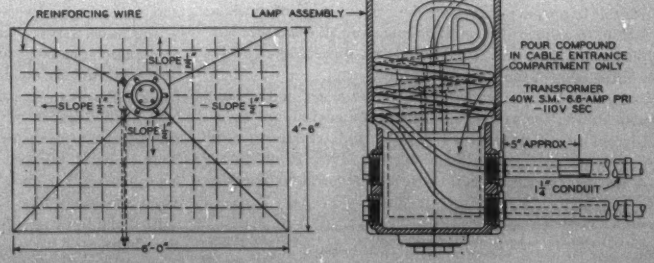

Figure 5. Installation of runway marker

EMERGENCY POWER

The utility of an adequate airdrome lighting system is dependent upon a constant source of electric energy. The Air Corps has not been satisfied with the reliability of commercial power and has developed automatically operated equipment to supply power in an emergency. As the first step in this development action was taken to provide distribution systems operating at either 2,300 volts delta or 4,000 volts star. For fields using higher-voltage systems, the necessary step-down transformers were provided. Two items of standardized equipment as follows were then developed which could be connected at will for either voltage:

1. *Primary Cubicle.* This equipment consists of a self-contained hand or automatically operated switching device. When

set for automatic operation, it is designed to transfer the load from the preferred (commercial) source to the emergency source in event of failure of one or more phases of the preferred source. This transfer is, of course, dependent upon the emergency source being energized and, to initiate this action, a 230-volt pilot source is provided to the emergency cubicle. The primary cubicle includes metering from the preferred source, instruments for determining the electrical load from either source, and overload protection from either source.

2. *Emergency Cubicle.* The emergency cubicle which operates in conjunction with the primary cubicle and power plant includes a battery charger, a voltage regulator, and a control panel. The latter consists of the necessary relays to start the power plant from a 12-volt battery source in event the 230-volt pilot circuit from the primary cubicle is de-energized and to provide automatic shutdown when power is resumed. The control panel provides intermittent cranking to facilitate starting, operation of the power plant at no load for three minutes after power is resumed, and automatic shutdown in event of dangerous operation such as lack of oil pressure or high temperature.

Figure 6 shows the power plant designed to operate with the cubicles just described. It is rated 93.8 kva at 80 per cent power factor. The plant, however, will carry 93.8 kw continuously at an ambient temperature of 110 degrees Fahrenheit with radiator cooling only. Additional cooling is provided by a thermostatically operated valve which bleeds in cold water when the coolant exceeds 140 degrees Fahrenheit. The equipment uses gasoline as a fuel. This equipment will handle airdrome lighting, radio, and other vital loads.

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Aircraft Lighting

A. D. DIRCKSEN

AIRCRAFT lighting consists of: landing lights, position lights (wing and tail), formation lights, cabin lights (dome and worktable), indicator lamps, bomb-release signal light, interaircraft control-lamp assemblies, and instrument light.

Landing Lights. The first landing lights on aircraft were attached to the lower surface of the airfoil or to the fuselage. These lamp assemblies used 240- or 420-watt 12-volt lamps, depending on the size and type of airplane. Later, to reduce the aerodynamic drag, the lamp assemblies were built into a mount, which was fastened to the leading edge of the wing.

The next improvement was the insertion of the lamp assembly in the wings and the use of a curved cover glass to conform to the contour of the airfoil. Because of the increasing use of deicers and the use of the front surface of the wing to carry load, the leading-edge lamp assembly has been superseded by the present standard electric retractable-type landing-lamp assembly, which is mounted in the lower surface of the airfoil. Experimental tests are being conducted on sealed-beam lamps for aircraft landing lamps. The use of these lamps would permit increased wattage and light output and eliminate reflector maintenance.

Figure 6. Power plant installation at Mitchel Field, Long Island, N. Y.

Position Lights (Wing and Tail). The Air Corps recently has standardized on the single-unit-type position light which will meet the requirements of the Civil Aeronautics Administration airline forward position lights and which will also meet the Air Corps formation flying requirements when used with a dimming resistor. The Civil Aeronautics Administration requirements for tail light is not met by the Air Corps because increased airplane performance can be accomplished by the use of a lamp assembly using a three-candlepower, T-3¼ miniature bayonet-base lamp.

The change from the two-unit wing-tip lights previously used by the Air Corps, which did not meet the Civil Aeronautics Administration requirements, to the single-unit wing-tip light was due to less aerodynamic drag of the one-lamp unit. This reduction in aerodynamic drag is increasingly important with the present and future type airplanes due to increasing speed and performance. The use of wing-tip lights to conform to the light-intensity requirements of the Civil Aeronautics Administration made possible the elimination of the passing or auxiliary position-lamp assembly, which consisted of a 50-candlepower lamp mounted in a four-inch-diameter parabolic reflector with a red cover glass.

Formation Lights. Formation lights are used by the Air Corps to permit formation flying of tactical airplanes and to permit the extinguishing of the airplane wing-tip and tail lights. The formation lights are located on top of the fuselage and wing surface to eliminate observance of the airplanes by ground personnel. To eliminate aerodynamic drag, the flush-type lamp assembly was developed using a three-candlepower, T-3¼ miniature-bayonet-base lamp with a shallow reflector and a suitable lens to project the light beam to the rear of the airplane. The formation lamp circuit is controlled by a dimming rheostat with an incorporated "off" position switch. The formation-lamp assembly uses a blue lens to reduce the visibility of the light signal to be seen by the trailing airplanes of a formation flight.

Essential substance of a paper presented at the AIEE Middle Eastern District meeting, Cincinnati, Ohio, October 9–11, 1940.

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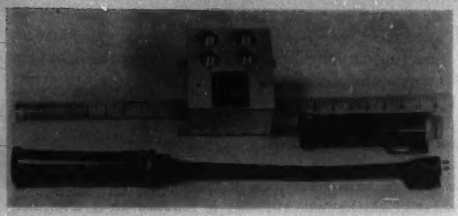


Figure 7. The inverter (above) changes airplane battery voltage (d-c) to 110-volt alternating current as required by the fixed fluorescent lamp assembly (right center) and the flexible lamp assembly (below)

Intensity of the ultraviolet radiation is regulated by the end knobs, visible light can be obtained by opening an aperture

Cabin Lights (*Dome and Worktable*). A new type of dome light recently was standardized by the Air Corps which uses a 21-candlepower silver-tipped light-shielded lamp. This lamp assembly is used in the airplane where no gasoline vapor will be present. In locations where gasoline vapor may be present a vaportight dome light will be used. This vaportight-lamp assembly uses an impact resisting coverglass and is suitably gasketed to render the unit vaportight. A worktable lamp assembly with a flexible arm is used for the navigator's plotting table. Development is being made on a lamp assembly using the new six-watt, nine-inch-long daylight fluorescent lamp. This lamp assembly will have incorporated in the base a 400-cycle reactor, lamp starting switch, and the control switch for the lamp circuit. This type of lamp assembly has been fabricated and tested and is being standardized by the Air Corps.

Indicator Lamps. Indicator lamps are used throughout the airplane for indicating fuel pressure, oil pressure, radio marker beam, camera operation, bomb release, etc. In the event that more than three signal-lamp assemblies are required, a common box housing the signal lamps is used. The box is provided with plastic light-transmitting nameplates which are painted with black enamel and then engraved and placed adjacent to their corresponding signal lamps. This provides suitable identification of the signal lamps, which is necessary because of the restriction of the number of colors of the color code. The test switch which is provided in this box permits checking of the lamps prior to and during flight. The use of the test switch eliminates the use of duplicate lamps in the circuit and is needed for safety purposes. In the event that three or less signal lamps are used, a shielded lamp assembly, using the three-candlepower $T\text{-}3^1/_4$ miniature-bayonet-base lamp and a suitable colored lamp cap is used.

Bomb-Release Signal-Lamp Assembly. A bomb-release signal light is used to permit formation bombing. The lamp assembly consists of two 100-candlepower lamps in reflectors and is located to project the light beam to the rear for signals to the trailing airplanes. One lamp and reflector giving a white signal is used to indicate the opening of the bomb-bay door. The other lamp with reflector is provided with a red cover glass which indicates the time of the release of the bomb. Because of the short duration of the current in the bomb-release solenoid, in which this lamp is connected, it is necessary to use a time-delay relay to provide a red-light signal of approximately three seconds.

Inter-Aircraft Control-Lamp Assemblies. Inter-aircraft control lights are used for communication between airplanes in formation in the event that the use of radio communication is not permissible. The assembly recently standardized by the Air Corps is a magnetically operated shutter type which intercepts the light between the lamp and the reflector. A signal is emitted when the coil is energized which pulls the light shutter from between the lamp and the reflector. This lamp assembly is approximately six inches in diameter and uses a 100-watt medium-prefocused-base lamp. The lamp assembly is hand-

Figure 8. With the fluorescent instrument-lighting system used in the Air Corps, only the luminous markings on the dials are visible inside the cockpit at night

operated and messages are sent by Morse or predetermined code.

Instrument Lighting. The Air Corps has recently standardized on fluorescent instrument lighting. This type of lighting employs the method of floodlighting the instrument panel with near ultraviolet light to increase the activation of the luminous material and to activate the fluorescent identification, range markers, and intermediate scale divisions. It is necessary that the lamp assembly be installed between the pilot and the instrument panel and so arranged as to floodlight the instruments uniformly with near ultraviolet light.

The fluorescent lamp assemblies, as standardized by the Air Corps, use the new four-watt six-inch $T\text{-}6\times 2^1/_2$ flat-bulb blue fluorescent lamp and a Corning 586 ultraviolet-light filter glass. This lamp assembly transmits near ultraviolet rays which activate the fluorescent and radioactive material. The fluorescent instrument lighting system which was developed at the Materiel Division, consists of the types *A*-8 and *C*-1 cockpit lamp assemblies which are the fixed mount and flexible arm types, respectively, and the inverter and the lamp-reactor control box.

The inverters, as standardized, which are used on aircraft having 12- and 24-volt d-c electrical systems, are for one-, two-, and four-lamp installations. Of the vibrator type, the inverters have the lamp reactors incorporated and are also designed to supply alternating current for the three-volt signal and compass lamps. On the larger airplanes, where either a 400-cycle 110-volt auxiliary engine generator or a 400-cycle rotary inverter is used to supply power for the Autosyn indicators, automatic pilot, radio, and instrument lighting, the lamp-reactor control boxes are used in lieu of the vibrator-type inverters.

Extensive flight and laboratory tests were made on the inverters and the lamp assemblies for the fluorescent instrument-lighting system, which was so named to distinguish it from the argon system. The argon lamp emits near ultraviolet light and produces the same effect as the fluorescent instrument-light fixtures except that the ultraviolet output is considerably less than that of the fluorescent lamp. Comparative flight tests were made between the fluorescent, argon, and individual lighting systems with the results favoring the fluorescent system.

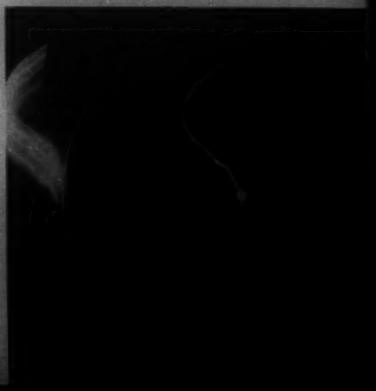
The project of instrument lighting by ultraviolet light was started by the Materiel Division approximately four years ago, but lack of suitable ultraviolet sources retarded its progress. The first flight tests were made with experimental 15-watt 18-inch blue lamps; because of the size of the lamps, they were located to the rear of the pilot. A very unsatisfactory condition resulted from this setup as the pilot's eyeballs fluoresced with the ultraviolet light that was intercepted by his eyes. The results of this test indicated the need for a small ultraviolet light source that could be controlled and located between the pilot and the instrument board and to floodlight the instrument panel uniformly.

The four- and six-watt blue fluorescent lights were developed by the lamp industry to meet these requirements. Due to a redesign of the lamp assembly, and the use of a special curved ultraviolet filter glass, only the four-watt six-inch blue fluorescent lamp was standardized. Fluorescent instrument lighting eliminates glare and reduces to a minimum the amount of light or the light level in the cockpit. This provides for improved visual acuity of the pilot between outside and inside the airplane cockpit. This is increasingly important with the present and future airplanes due to the increase in speeds and maneuverability and for formation flying. The difficulty encountered with reflections of the lighted instruments on the windshield and windows is reduced to a minimum with the reduced light level obtained by the fluorescent lighting system as against the superseded individual instrument lighting system. The type *C*-4 flexible cockpit-lamp assembly (spotlight type) is used for map illumination and for the auxiliary instrument-lighting system.

Empire State Lightning Studies Continued

BEGUN in 1935 under the direction of Doctor K. B. McEachron (A'14, F'37), the study of lightning strokes to the Empire State Building in New York, N. Y., has been continued by the General Electric Company. During the 1940 lightning season, the tower of this building, the top of which is some 1,240 feet above ground, was struck by lightning at least 20 times. Detailed records of these strokes were kept by P. C. Edwards (A'38) who, assisted by Mrs. Edwards, had the assignment of photographing and studying the volts striking the skyscraper during that season.

As in previous studies (*EE, Dec. '38, p. 493–505; 507*) the 1940 studies included the taking of oscillograms at the Empire State Building and photographs of the strokes with a moving film camera from the 39th floor of the building at 500 Fifth Avenue. A remote-control automatic camera on the roof of the Printing Crafts Building on Eighth Avenue provided right-angle views of the bolts hitting the Empire State structure. Records from the two buildings provide three-dimensional information concerning the bolts. During the 1935 season, 4 bolts were recorded; during the subsequent seasons the number of bolts studied were: 1936, 22; 1937, 41; 1938, 24; and 1939, only 1. The photograph reproduced here is considered to be the best one taken during the 1940 season. This bolt occurred at $9{:}11^1/_4$ p.m. on August 6. Storms that night kept the couple at their instruments from early evening until 4 a.m. the next day. The duration and multiple nature of the stroke may be seen from the reproduction.



Recent Applications of Radio to the Remote Indication of Meteorological Elements

HARRY DIAMOND

Lightweight radio transmitting equipment, carried aloft by balloons, is being used to obtain remote indications of meteorological elements, from the stratosphere. Such equipment also makes possible periodic observations from unattended stations in remote locations.

IN THE past few years there has been increasing application of radio to the extension of the geographical boundaries within which routine weather observations may be made. Heretofore, weather observations were limited to those which could be obtained by human observers near the weather instruments. The use of special measuring devices which automatically translate the variations of the meteorological elements to be measured into corresponding radio signal variations has removed many of the practical limitations. Measurements may be obtained from any point where it is possible to locate the measuring and auxiliary equipment, and they may be recorded (automatically, if desired) at any convenient point within radio contact of the measuring point. Thus, upper-air observations may be obtained economically well into the stratosphere by sending aloft, attached to small balloons, meteorological instruments with associated miniature radio transmitting equipment. Also, periodic observations may be had from isolated locations such as mountain peaks, small islands, floating buoys, and the like, where unattended equipment may be serviced at infrequent intervals but where it would not be practicable to maintain an observation staff. The government's meteorological services are already making extensive use of the balloon-carried equipment (radio sondes), daily upper-air observations being obtained at a large number of land stations in continental United States, Alaska, and the Caribbean, and at shipboard stations in the Atlantic and Pacific. The use of automatic weather stations at remote isolated locations is just beginning, but already quite a number of installations are in project.

METHODS AND EQUIPMENT

Measurements required in routine upper-air observations include: barometric pressure, air temperature, relative humidity, and wind velocity, all as a function of altitude. Altitude is determined from the air density computed on the basis of the pressure, temperature, and humidity observations. Measurements that may be required in observations at remote isolated locations include: barometric pressure, air temperature, relative humidity, surface winds, precipitation, visual range (visibility), ceiling height, amount of sky overcast, and so forth. Present-day technique has not yet provided for the remote indication of all these elements, as will be evident later from the description of equipment. However, the methods are quite general and probably capable of extension to include the elements not now measured.

The methods used are characterized primarily by the means employed for translating the response of the measuring instruments into predetermined variations of some characteristic of the radio signals, whereby remote indication is provided at the receiving station. The emitted radio wave may be keyed according to code or to time, or the frequency of the carrier wave or of a signal modulating the carrier wave may be varied. In view of the very low power developed by some of the measuring instruments, the translating means must have negligible reaction upon the measuring instruments. This requirement automatically rules out remote-control and indicating methods, used successfully in radio signaling practice, which employ special coding sequences.

Olland or Time-Cycle Method. Figure 1 shows a translating method which is applicable when the instrument response is in terms of the mechanical deflection of a pointer. This method was devised by the Dutch scientist Olland in 1872 to send along wire lines from a mountain top measurements of barometric pressure, air temperature, and relative humidity. It has formed the basis of a large number of radio-sonde designs in this country and abroad. In the simplest form, the instrument pointers are mounted concentrically, each pointer deflecting over an arc of about 120 degrees. The instruments are calibrated in terms of the angles of deflection of their pointers from zero reference positions (R_P, R_T, and R_H in figure 1). The deflection angles are measured in terms of time by a sweep arm

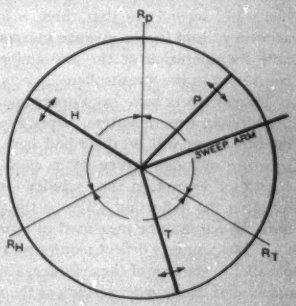


Figure 1. Principle of Olland method

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rotated at constant speed (1 rpm) by a clock. In moving, the sweep arm makes contact with distinctive index markers corresponding to the pointer reference positions and with wipers carried by the pointers. These contacts may be made to key the radio transmitter on or off, so that the elapsed time between the occurrence of a keying pulse corresponding to a reference contact and that corresponding to a pointer contact serves as a measure of the angle of deflection of the particular instrument pointer.

As described, the method is subject to two serious disadvantages in radio-sonde application: (*a*) the pulsating angular motion of the second hand (two beats per second in the average inexpensive clock) results in coarse subdivision of the deflecting scale (three-degree minimum for two beats per second) so that there is insufficient measuring accuracy; and (*b*) the average inexpensive clock is unsuitable for operation at the low ambient temperatures encountered in the stratosphere.

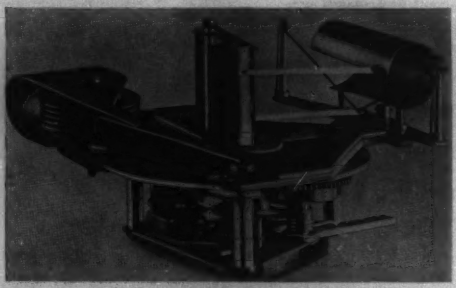

Figure 2. Radio sonde of Blue Hill (Mass.) Observatory using three-turn clock-driven spiral for dividing the pointer scales

These defects have been overcome in a variety of ways by different experimenters. Only a few of the outstanding modifications will be described here. Lange[1] employs a rotating cylinder driven by a clock, a three-turn spiral contactor wound on the cylinder forming the means for dividing the deflecting scales of the pointers into angular units which may be measured in terms of time (see figure 2). The pointers deflect along arcs that are substantially parallel to the axis of the cylinder, a single index marker at one end of the cylinder serving as the zero reference marker for all three pointers. It will be evident that each turn of the three-turn spiral will subdivide only one-third of the possible arc of deflection of each pointer; hence, three revolutions of the cylinder will be required for subdividing the complete deflection arc. Thus, the unit of scale subdivision imposed by the pulsating angular motion of the cylinder will be only 1/360 of full-scale (for a two-beat-per-second clock) was compared to 1/40 of full-scale in figure 1. Thermal insulation of the clock is used in this instrument to obviate defect (*b*).

Curtiss, Astin, Stockman and Brown,[2] have devised a miniature constant-speed d-c motor for rotating the sweep arm, thus overcoming both disadvantages simultaneously. The motor operates from a 1.5-volt penlight cell and draws only eight milliamperes.

Major Bureau,[3] in France, adopted a somewhat different method for eliminating the clock. He employs a spring motor for driving the sweep arm and, at higher speed, a toothed disk. The teeth pass successively between the plates of a capacitor, thereby modulating the radio transmitter (by detuning). The angle of deflection of an instrument pointer from its zero reference position is thus measured directly in terms of the number of cycles of modulation occurring between the reference and pointer contacts. The disk has nine teeth with a gap in place of a tenth, thereby facilitating the count of the modulation cycles at the ground station. This arrangement eliminates the requirement for constant-speed drive of the sweep arm.

Kenneth Whitney of Julien P. Friez and Sons Company has devised a method (unpublished) which utilizes a miniature synchronous motor for driving the sweep arm. An audio oscillator, utilizing a special transformer, provides voltage of substantially constant frequency for driving the synchronous motor and also for modulating the carrier wave of the radio transmitter. Voltage of the modulation frequency, after detection and amplification at the receiving station, is used for driving a recorder drum in exact synchronism with the sweep arm on the balloon. The recorder scale may therefore be graduated in terms of the deflection arcs of the instrument pointers.

Carrier-Frequency Variation Method. Figure 3 shows the electric circuit arrangement of a radio sonde based on a method devised by Väisälä[4] and on modifications introduced by H. Dahl, O. Dahl, and M. Jenssen.[5] The three variable capacitors *B*, *T*, and *H*, controlled respectively by the pressure, temperature, and humidity instruments, and the fixed capacitor *N* are connected successively in parallel with the tuning capacitor of the radio transmitter by means of the motor-driven switch *R* (1,500 rpm). The successive

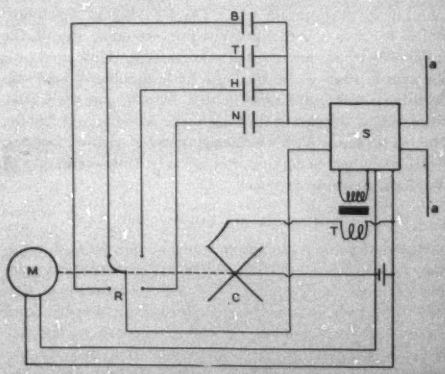

Figure 3. Circuit arrangement of the Norwegian radio sonde

values of the carrier frequency thus provide means for evaluating the responses of the measuring instruments, the fixed frequency serving as a check on the transmitter performance. The range of frequency variation used is approximately ten per cent of the carrier frequency (that is, 2.5 megacycles at 25 megacycles).

Rotating synchronously with the switch R is a four-contact switch C which serves to interrupt the direct current through the primary winding of transformer T at exactly the instant when R connects one of the capacitors into circuit. A high-voltage pulse is thus applied to the transmitter (on the secondary side) which is sufficient for operating the transmitter for a short interval. This method limits the battery needed in the radio sonde to a single low-voltage cell.

The receiving and recording arrangement used is shown in figure 4. The receiver-tuning range is traversed slowly (twice per minute) by means of a motor-driven cam. The

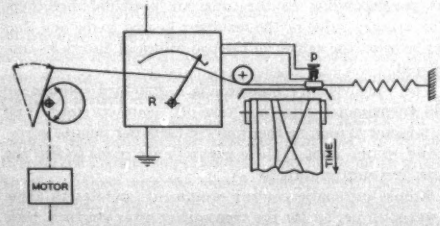

Figure 4. Receiving and recording equipment for Norwegian radio sonde

recorder pen moves across a paper chart synchronously with the tuning control. A relay operates the pen whenever the frequency of the receiver corresponds to one of the four frequencies of the radio sonde.

Modulation-Frequency Variation Method. A radio sonde that employs variation of the modulating frequency as the means for translating the response of the measuring instruments[6,7] is in present widespread use by United States Government agencies. The audio oscillator is of a special kind, such that the generated frequency is controlled by the value of resistance connected in its grid circuit. Hence, the measuring instruments may be of conventional types mechanically controlling variable resistors, or of special types designed to vary inherently in electric resistance in response to variations in the meteorological elements which they measure.

The capillary electrolytic thermometer and the electric hygrometer are of the latter class. The former utilizes the effect of temperature on the conduction of electricity through an electrolyte; the latter is based on the effect of moisture on the conductivity of a hygroscopic salt. The two units are connected alternately into circuit by a relay controlled by the pressure-measuring instrument. Pressure measurements are based on an actual count of the switching operations, this count being facilitated by the connection of fixed index resistors into the circuit at predetermined pressure levels.

The audio-modulation type of radio sonde affords several distinct advantages over other types. The need for a clock or motor is eliminated. The electric instruments may be controlled in manufacture to give predetermined characteristics, thereby reducing the amount of calibration required, and hence the cost. The electric instruments may be designed for very rapid response; this is of particular significance in the case of the electric hygrometer since the corresponding mechanical instrument is very sluggish. Finally, the reliance on mechanical contacts is limited to the pressure instrument only. A disadvantage of the audio-modulation radio sonde is the rather costly frequency-measuring and recording equipment required at the receiving station.

AUTOMATIC WEATHER STATION

All the methods described in the preceding section are applicable to the automatic weather station, provided that the variations of the meteorological elements to be measured can be converted into instrument responses of the required nature. The ideal automatic weather station would be one in which a minimum amount of modification of standard meteorological instruments is required to adapt them to the translating and transmitting means.

A setup that employs the Olland principle has been developed by K. O. Lange, C. B. Pear, and T. Dickey.[8] A six-volt electric clock drives a cylinder with a contact helix, turning it once per hour. During the first half of this interval, signals are transmitted for eight wind directions, wind velocity, sunshine, pressure, temperature and humidity; in addition, there are four reference contacts. The clock movement turns on the filament current of the 125-megacycle transmitter for one-half hour out of each hour and the contacts of the various meteorological instruments switch the plate battery into the circuit. The transmitter is operated by dry cells.

The reception is the same as with the Olland type of radio sonde, employing a chronograph recorder. A carriage moves down and up along a drum in the course of one hour. The graph is made on the way down, since all signals occur only during the first half-hour out of each hour. A special relay mechanism synchronizes the recorder with the automatic weather station at the beginning of each cycle.

Figure 5 shows the electric-circuit arrangement of an automatic weather station[9] in which some progress has been made toward the use of standard instruments. The method of remote indication used is identical with that employed in the audio-modulation type of radio sonde. The variation in a meteorological element is converted into a change in electrical resistance which in turn produces a change in rate of keying the emitted carrier wave. Very low keying frequencies are used, ranging from 0.15 to 3 cycles per second. The low frequencies allow direct keying of the radio transmitter and the use of simple equipment for frequency measurement at the receiving end. In fact, all that is required in the usual case is a stop watch and head phones.

The translation of resistance variations into corresponding variations of keying frequency is accomplished by

means of a keying oscillator of trigger type. The circuit arrangement is shown in figure 5. The oscillatory circuit $L_1C_1L_2$ is tuned to a frequency of about 1 megacycle per second. The 1-megacycle oscillations are interrupted at a rate determined by the time constant of the resistance-capacitance combination in the grid circuit. Here, R is the variable instrument resistor (generally in series with a limiting reference resistor of about 40,000 ohms) and C is a stable capacitor of about eight microfarads capacitance. The output of the keying oscillator is coupled to a half-wave rectifier which, in turn, applies negative voltage to the input of the relay control tube. The smoothing filter R_3C_3 in the plate circuit of the keying oscillator converts the groups of 1-megacycle oscillations into corresponding pulses. After rectification, these appear as negative pulses on the grid of the relay-control tube; their duration is controlled by the time constant of the network R_3C_4. The relay is normally in the actuated position; the armature is released upon application of the negative pulses to the grid of the relay-control tube and remains open so long as the grid bias is sufficient to keep the current through the relay coil below the "pull-in" value. The back contact of the relay thus may be used for keying any conventional radio-telegraph transmitter; there is seen to be no limitation on the power output of the transmitter. In figure 5, the keying relay is in parallel with the key of a conventional radio-telegraph transmitter.

The pressure, humidity, and rain-gauge instruments are of standard design, the rain gauge being of the weighing type. In each instrument, a relay-operated clamping bar is added for clamping the instrument pointer against the edge of a wire-wound resistor when an observation from that instrument is desired; this provides the means for converting the instrument deflection into variable resistance. The instrument pointer is allowed to swing freely except when an observation is made, thereby limiting friction to that normally present in the standard instrument.

The temperature element consists of a glass capillary tube filled with an electrolyte having a high temperature coefficient of electrical resistance; the resistance of this device is thus a function of the ambient temperature. This arrangement is the same as that in the audio-modulation type of radio sonde except that a tube of greater life is used.

The wind-direction indicator (of standard type) has eight 45-degree contact segments corresponding to the eight principal compass points. A different fixed resistor is connected to each segment and thrown into circuit when the wind vane assumes that direction. Directions intermediate to any two principal directions are indicated by taking advantage of the oscillation of the wind vane about its average position; such oscillation tends to connect into circuit successively on a proportional basis, the two resistors corresponding to the adjacent principal directions. The average value of the resultant keying frequency thus lies between the values for the two principal directions considered.

The wind-velocity indicator is a standard commercial cup anemometer with the "take-off" contacts stepped up by a factor of four, so that four contacts per minute correspond to one knot. These contacts are made to key the radio transmitter directly.

Simple automatic control equipment operates to allow a warm-up period for the transmitter after starting, then to send out the station call letters, a reference frequency, and finally the several observation frequencies corresponding to the desired measurements each preceded by an identifying code. The sequence is carried out by means of

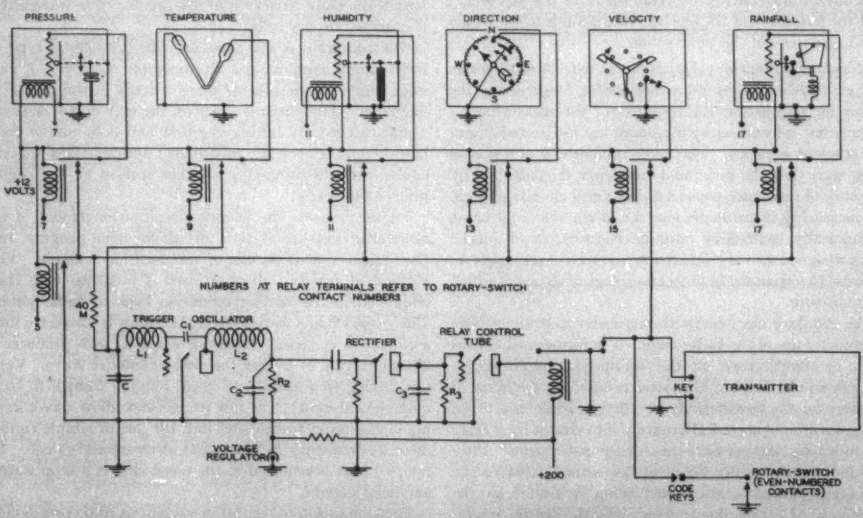

Figure 5. Circuit arrangement of automatic weather station

an automatic rotary switch, certain odd-numbered contacts of which operate the relays shown in figure 5 which are given corresponding numbers. Certain even-numbered contacts of the rotary switch connect coding circuits (formed by code disks and associated switches) in parallel with the keying relay to key the transmitter in accordance with the station call letters at the beginning of a sequence and with the code letters *P*, *T*, *H*, *D*, *V*, and *R* preceding the observations of pressure, temperature, humidity, wind direction, wind velocity, and rainfall, respectively. The whole sequence is started by a clock at preset times of day, and is repeated twice for convenience.

The functions of the various relays associated with the odd-numbered contacts of the automatic rotary switch are evident from figure 5. Relay 5 connects only the 40,000-ohm reference resistor in the grid circuit of the modulating oscillator, thereby providing a reference frequency, nominally 3.0 pulses per second; this frequency serves as a check on frequency drift of the oscillator and as a means for correcting the various observations (except wind velocity) for frequency drift. Relays 7, 11, and 17 connect the corresponding instrument resistors in series with the reference resistor; companion relays operate the clamping bars for these instruments. Relay 9 connects in the temperature resistor directly, leaving the reference resistor out of circuit; this provides for increased sensitivity of indication at the higher temperatures. The functions of relays 13 and 15 used with the wind-indicating instruments are self-evident. The contact switch in the wind velocity indicator is connected in parallel with the keying relay and keys the transmitter directly.

An experimental automatic weather station of this type installed at the Naval Air Station, Anacostia, D. C., is shown in figure 6. The top compartment takes the form of the conventional ventilated shelter for housing the temperature- and humidity-measuring elements. The wind vane and cup anemometer are mounted on the top of this housing. The middle compartment houses the control and keying unit. The lower compartment houses the radio transmitter (15 watts, 3,295 and 5,072.5 kilocycles), power supply including a storage battery and dynamotor, and the timing clock.

In conclusion, it is of interest to focus attention on the measurements desired in the radio-sonde and automatic-weather-station services that have not been provided by the equipment described. As already indicated, the radio sonde should provide measurements of upper-air wind speeds and directions. This information may be obtained by tracking the path of the radio-sonde balloon as it is carried away from the observing station by the winds. Radio direction-finding methods may be applied for determining the azimuthal and elevation angles of the balloon, using the emission from the radio-sonde transmitter. These angles, together with information on the corresponding altitudes of the balloon would be sufficient for computing the successive balloon positions. Unfortunately, the precision of determination of angles required (of the order of 0.1 degree) is considerably greater than is obtainable in the present state of the art. Some work in this direction has been done by L. C. Yuan and S. S. Mackeown.[10]

Similarly, the automatic weather station should provide measurements of visual range (visibility), ceiling height, amount of sky overcast, and the like. It is evident that such measurements will require the use of photoelectric tubes. These are devices the electrical resistances of which vary with their illumination, and which thus can be incorporated readily in the circuits described in figure 5. However, the methods of measurement to be employed have not as yet been determined.

Figure 6. Experimental automatic weather station installed at Naval Air Station, Anacostia, D. C.

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The Technology of Motion Pictures

DOUGLAS SHEARER

An outline of some of the technical problems involved in the production of modern sound motion pictures

ANY GRAPHIC ART seems to involve an element of the dimension of time. For example, printing allows us to review in our imagination the happenings of previous times or the prediction of future happenings; paintings indicate to us things that happened in the past, and to happen in the future; likewise sculpture seems to contain that "mysterious" element of either preserving or reproducing happenings in time.

In the motion picture, which may be called a graphic art, certainly the element of time is more intimately involved than in any of the other three arts mentioned. A reel of film may contain pictures of the dead villain, the live villain, and the unborn villain; it contains the beginning and the end; and that is all contained in that one reel of film at that very same time. In that reel of film those things have happened or they are going to happen. You can make it go backward or frontward. You can cut out a piece in the middle; you can stick it together and have that which happened previously happen today and then show the retrospect. You can delay the action and shift it further along in the story. You can take the element of time and just move it anywhere you wish.

Time without geographic solidity and actual physical body would be as listless as physical body would be without time, so in the motion picture we have to put something tangible on the screen. We have to make an entertainment out of it. I believe the question of appeal of motion pictures to the general public is based on two main factors: One might be called the "mysterious" element of time involvement, and the other the presentation of realistic geographic records. That is, when you see a motion picture you feel that you are seeing something that either did happen, or could happen if it is a good one.

The public insists on realism in motion pictures. When we compare motion pictures to the legitimate stage we do not see the same amount of realism. If on a conventional, legitimate stage an actor goes out a door and the walls shake back and forth—well, that is not especially annoying. It is just an event you expect to occur. However, if you were to see the walls shaking back and forth in a motion picture when someone walks out a door it would disturb your sense of realism.

In the old days of pictures when a railroad train came tearing down the track many thought that this was a real happening. In the original pictures they did film actual happenings to a large extent. They enacted the complete physical events in front of the camera. That was largely due to lack of having developed technique. In the developing of this technique there have been engineering developments. Engineers have come to the business, although some of them may not be recognized as engineers. One man in the business is called the art director, but he is actually a motion-picture engineer. An art director is usually thought of as an artist drawing sketches or building sets in architecture. Actually, the art director is the man who takes the written script and puts it into physical accomplishment. He does the things that the script calls for. It might be a hurricane, it might be an earthquake scene, or it might be a ship wrecked at sea. It might be something that is not associated with art whatsoever in any sense of the word. This art director, for instance, must visualize whether we can invent a wave machine that will play tons of water on the deck of a boat at sea in the studios; he must be able to have a forest fire take place; he must build sets with openings where light can be introduced; he must have the sets arranged so that the geography of the picture can be brought about from the movements of the camera and also the microphone.

The question of engineering in the picture business has changed from going out and photographing real objects and real happenings to creating these things in a sense. Again we utilize in the picture business more and more of the time-control elements. We can shoot one scene ahead of another. We can take the front part of the story last. We can make a whole set of pictures by using a little retake and then inserting it in sequence. The technique from an engineering standpoint is real. We have more and more freedom in the handling of climaxes in order to produce consecutive impressions upon the audience.

"GEOGRAPHY" OF SCENES

Unknown to most audiences we have to resort to a little trickery every time we show them something new on the screen. We have to give them the geography of the set. That is usually accomplished by showing a "long shot." That is, a set or house, or whatever the scene is, must be firmly implanted upon the audience's mind as to the geography. The kitchen must be on the right hand or the dining room on the left hand or the parlor here or the stairway going upstairs over in that direction, and so forth. After we have shown the audience exactly how this set lies we can move in for closer shots. If we keep our actors moving in the right directions, the audience will notice that they are going to the

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Essential substance of an address delivered at the AIEE Pacific Coast convention, Los Angeles, Calif., August 27–31, 1940.

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kitchen, the dining room, or upstairs, without showing any part of these rooms again. We must establish in the minds of the spectators the geography of that particular set; and once that geography is established we can shift around that set with close shots, reverse angles, or other directions.

The art director plays a part in this. The camera man becomes a dimensional engineer in that sense. He must maintain that geography in his shots. The editor who cuts the film, even apart from the dramatic presentation of the story, must keep his geography and his time exactly correct. Assume, for example, that a man is going from his home to his office. If he starts for his office and moves on the screen from left to right you must always show him going in that same direction, otherwise you might think that he had forgotten something and was returning to his home. We always show steamers going to Europe in one direction on the screen and from Europe in another, so as not to confuse the audience. We want to keep the geography straight. We want to keep it simple and in that way the spectators can follow the story without having to solve the problems of the mechanical part of the picture. If a person is walking toward the camera in one part of his trip from home to the office then he must pass the camera on the correct side even coming toward it from a very small angle. Those are just some of the little dimensional geographic aspects of motion pictures that people do not ordinarily think about.

PROCEDURE IN MAKING A PICTURE

The procedure of making a picture starts with the man we call the producer. He is supposed to select a story that is suitable, and he also tries to select the cast and the crew. He is the man who decides whether a certain amount of money should be spent on a given story in an attempt to make a picture out of it that will bring back the original investment plus, we hope, some profit. By the way, if we just get our money back on an average picture we think we have done pretty well; our profits come principally from the outstanding pictures.

After a story has been procured, it is given to a screen playwright, who rewrites it in terms that can be couched in the medium of the screen. The playwright must cut the story down to be shown in the minimum time that can be allowed for that picture. A legitimate play may take $2^1/_2$ hours to run, but we have to condense the motion picture into an hour or $1^1/_2$ hours, or possibly even 40 minutes. That takes a special kind of writing. The playwright must visualize this picture as presented on the screen.

After the playwright has rewritten the play, it is turned over to a director to make the picture. This director has the aid of a casting director who selects, preferably from our own staff, the cast of characters. This staff is an investment that we have and which we have developed; in fact, it is the chief capital asset of the picture. The director is then assigned a crew. The crew consists of the art director, the electricians, certain mechanical people, the sound recordist, the assistant director, and the manager for that group. These people all take their parts in the various parts of the picture. The assistant director breaks the story down into the actual sets and scenes that have to be made in conjunction with the art director; that is, the art director's work is laid out.

Most people that are employed for a picture are used right at the start, all the scenes requiring a large cast being shot at the beginning. As we come to the end of a picture we find that we are winding up with only two or three people out of the original group that was engaged. That is necessary for several reasons. In the first place it is more economical. Secondly, if we use a man in the early part of the picture and then have him wait until two weeks later it would hold up his activities for any other picture; also we would run the risk of his becoming ill and holding up the picture completely.

When the director actually begins to make a scene he may make changes according to his view of the situation at the moment, but generally he follows the script. He has to choose the people to fit the characters of the story. He must see that all members of the cast act their characters in all the scenes throughout the story. That is the director's function. He must make his people live, interesting characters. The degree to which he does that has a great effect on producing either a drab, uninteresting picture or one where every scene is interesting, the whole picture is interesting, and it is a success.

Getting back to a little bit more of the physical side, I must not leave out the editor. The editor may be the producer with a physical assistant doing all the actual film cutting and then matching them together in their proper story relations. These scenes must be associated so that they form the right impression. When that cutting is done the picture is taken out and tried on an audience at a preview. That tryout is a test for us, not the audience. We really make them work for us. One can become quite expert in feeling the reactions of audiences without even having them say anything. We sense their reactions at the preview. We then go back and re-edit the picture. We do not necessarily have to make some of the scenes over. We can do wonders just by editing the picture and speeding it up, or eliminating objectionable scenes.

ELECTRICITY USED FOR LIGHTING

Some figures on the electricity used for lighting the scenes may be of interest. We had one of our biggest sets in the making of "The Wizard of Oz." On that set we used 40,000 amperes of direct current at 120 volts. That is a lot of amperes all going into light; in fact, we were overloading all of our equipment. We could hold that load for only about four minutes at a time. We had all of our own equipment and a lot of rented equipment on the set. This 40,000 amperes at 120 volts raised the temperature of the stage at the rate of some ten degrees a minute, even with the ventilating system operating at full load—90 cubic feet of air per minute and 150 tons of refrigeration. To supply the direct current we used five 500-kw, five 400-kw, and four 300-kw motor generators.

The annual consumption of purchased electric energy of the Metro-Goldwyn-Mayer Studios is 21,000,000 kilowatt-hours. We buy this energy at a rate that would not

make it possible to generate our own, and at the same time take the risk of interruption in service. Our energy comes to us from a great network. We could not possibly depend on any plant of our own, and we could not afford to have a standby plant to take care of any emergency. Our annual cost of electric energy is $150,000.

By the use of synchronous-motor drive for our motor generators, we have a power factor of 0.95. As to lamps and lighting equipment, we have 140 150-ampere arcs, 54 120-ampere arcs, and 80 40-ampere arcs. In incandescent lighting equipment we have about 900 5-kw lamps and 67 3.2-kw units.

DEVELOPMENT OF SOUND PICTURE

Getting back to the picture itself, and particularly sound pictures, many people have asked: "Who developed the sound picture?" I have always said that the real invention was silent pictures because when the motion picture was first developed, and it happened subsequent to the phonograph, it was unquestionably Edison's intention to have motion pictures accompanied by the sound of the phonograph. The real discovery was brought about by the physical inability to present a good sound picture, that is, a purely mechanical recording and recreation of sound either in synchronization with the picture or with adequate volume and fidelity. Then somebody got the idea that perhaps motion pictures without sound might work. They then found that motion pictures without sound would entertain, so the real discovery was silent pictures.

The technique in those days was entirely different from that of present sound pictures. The time element was even more free. The entire pattern of the story could be changed by merely inserting a title. We had a great scope in what we called "mugging." In that way actors put over extremely broad expressions with their faces and their gestures. The editorial and cutting aspects were entirely different from what they are today. Silent pictures reached a certain point where the imaginative ability of the audience was even more free than it is now.

When we come to sound pictures we come closer to reality. We had to make people actually say what we wanted them to say. We narrowed that imaginative border and tied things right down to facts. Naturally, that produced a bit of chaos in the picture business; it also produced some chaos in the audience. A further move in the direction of realism is the present movement toward color. We find that in looking at black-and-white pictures there is no imaginative problem, but with color the mind goes around the frame line—there is a tendency for one to believe only what he sees on the screen; one loses all of the ability to retain imaginative value.

The coming of sound to pictures followed the development of the vacuum tube and the ability to amplify. It was not until telegraphy reached the point of becoming a means of communication and the radio field made reliable amplifiers that there was any possibility of reviving sound pictures. After that operation, a second step took place which was very important. That was the work done with electrical phonograph recordings. The complete technique of electrical phonograph recording was developed before sound pictures again were considered, at least seriously. When that had been done there remained at least mechanically only one phase. That was the simple step of synchronization, the turning of the disks with the running of the motion-picture machines; that involved many problems.

The next problem concerned the theaters. We had to equip 18,000 theaters before we could have an outlet. That was a gigantic feat to accomplish in the time that it had to be done. Great credit is due the staffs of engineers and the manufacturing groups of the electrical companies who undertook that work.

We also had our problems in the studio. Our actors and actresses were naturally completely at a loss as to what to do with sound. The stage actors also had their troubles because stage acting is so broad in its presentation. The stage actors looked rather silly because they were used to seeing overdone action, and the silent-picture people, of course, were not broad enough. There were not only certain personnel difficulties in the acting business, but there were the technical problems of making sound pictures. We had to use microphones at distances which formerly were not used in broadcast work. That is, we had to get to the point where we could have the people walking many feet away from the microphone and not particularly paying attention to where they walked.

Now we will see what some of the electrical problems were. The output, for instance, from a conventional microphone from a person several feet away talking in an ordinary tone of voice is 10 or 12 decibels below an energy level of 19×10^{-11} watt. All of the recording circuits had to be run around the stage, and the lights and the people introduced enormous pickup problems. It was almost impossible to eliminate the noise pickup.

Our channels were generally capable of amplifying the initial signal 120 decibels, or a trillionfold. We do not use all of that; we reserve about 40 decibels for control purposes. After being amplified we put it on the film in the form of a permanent record. Then the signal comes off that film onto a photoelectric cell and is amplified about a trillion times before it gets to the loud-speakers in the theaters. Thus the initial signal is amplified a trillion times twice before it reaches the audience. To preserve the plainness of the signals and to free the system from noise taxed the art of modern communication to the limit.

I believe that sound pictures require the highest ability of any telephonic effort. We know that the ordinary telephone conversation is limited in frequency band. Telegraphy, of course, has a very narrow band. Television requires a very broad band, but I believe that sound pictures demand the highest degree of fidelity. One reason for that is that we put a picture of a person on a screen, and then when the sound comes out it must sound like that person. I do not mean just like that particular individual, but it must sound human.

AN UNSOLVED PROBLEM

One of the problems of modern equipment still remaining unsolved concerns the theater systems. The usual trouble with the majority of theater systems today is that

they have insufficient undistorted wattage. Many have much less wattage than a good home radio receiving set. At the studios, we have an auditorium that is only 60 feet long, 50 feet wide, and 20 feet high, but yet we believe that we need 50 watts in that room in order that there will be no distortion from the reproducing apparatus. The fact that many theaters have this low wattage limits the initial dynamic range that can be put on the film. We also limit the frequency range for other reasons. We have to break away from the theater that has an ideal situation, an extremely broad frequency band, and we have to avoid the errors that happen when we go too far. The same thing applies to the low frequencies, although that problem largely concerns the recording operation.

As to the reproduction of sound in the theater, the average engineer might think that if the sound were reproduced in its original form it would sound like the original. That does not happen. If the sound were reproduced in the average theater at precisely its original volume, possibly we could use the original frequency characteristics and reproduce it as a facsimile. However, the sound must be amplified when reproduced with the picture, particularly in the larger theaters. Because the human ear is not equally sensitive to all audible frequencies, speech sounds unnatural when amplified; this is because all frequencies over a rather wide range are amplified equally, which results in apparent increases in the volume level of certain frequencies as far as ear response is concerned. For that reason, certain frequencies in the sound record on the film must be altered so that the sound will seem natural when amplified for reproduction in the theater.

BINAURAL EFFECT LACKING

One other loss that has to be approximated at times is the loss of the two-ear properties that we all have for listening. In that respect we can analyze it just the same as eyesight. We look at a scene with one eye, and then if we look at it with the other eye we see it from an entirely different angle. We have two images really presenting two distinct pictures. In scanning those pictures we form a concept of solidity.

In sound we have the same effect in respect to our two ears. We hear the sound closest to one ear sooner than with the other ear. That presents two "pictures," one quite different from the other. When we "look" at those immediately we begin forming two images, and we form a concept which we call our hearing. That concept is one of solidity and space just as in eyesight. We can tell whether a person is far, near, at the right or left, behind, above, or below. A peculiar property of the human hearing system is the ability to switch what we in the motion-picture business call the "attention factor" without any physical motion. We can listen to a person with either ear; we can ignore the person behind; we can listen to a person across the table and ignore the rattling of dishes. This gives people the ability in their hearing to lower the sound of those things in which they are not interested and to listen to the things in which they are interested.

Some Statistics Compiled by the Academy of Motion Picture Arts and Sciences (for the Year 1937)

Total number of theaters in the United States	18,000
Total seating capacity	10,924,000
Total weekly attendance	85,000,000
Estimated gross box office receipts for year	$1,000,000,000
Tax paid to Federal Government during year	$100,000,000
Distribution of box-office receipts, per cent:	
Theater staff and management	25
Real estate	15
Advertising	8
Lights	5
Interest and dividends	5
Other taxes and miscellaneous	344
Film rental	535
Proportion to studios	25
Proportion to distributors	10
Capital invested—in U. S. theaters	$1,800,000,000
In motion picture studios	100,000,000
In distribution companies	20,000,000
Employees—Exhibitors	214,000
Studios	28,500
Distribution companies—Wholesale	12,500
Retail	241,000
Payroll for year—Exhibitors	$250,000,000
Producers	91,000,000
Distributors	26,500,000
Amount paid to "extras" during year	$3,000,000
Number extras employed	16,000
Average days worked by extras during year	18.4
Average daily wage paid to extras	$10.03
Average annual earnings of extras	$187.00
Number of feature pictures produced during year	608
Number of positive prints from each picture	250
Average number of runs per positive print	300
Number of feet of positive film produced in year	2,000,000,000
Cost of producing positive film	$20,000,000

What happens when we record that sound? A microphone is only a single-channel device. It has no means of picking up any two-way images. The microphone records the exact physical value of all sound that reaches it. This recording takes on a true physical importance and not the psychological importance. We lose the binaural or two-ear hearing ability, and then we have to try to substitute something for it.

As an example, suppose we have a group of people dancing around a floor; their feet, apparently, make more noise than we usually hear. At a dance we do not listen to that noise; we listen to what a person has to say or to the music, so we have to diminish this actual noise. If we have a bunch of people chattering in a mob scene something like this might go on: "Mr. Conway, we are having too much noise." Then Mr. Conway says: "I like it." "But," we say, "Mr. Conway, you do not hear it that way. It will be so much louder on the screen." The argument then goes on and we will finally say, "Mr. Conway, you just leave out that feet shuffling and then we can run in as much of it as we need." He just did not hear that shuffle with both ears as it would be recorded.

The question of that loss of binaural hearing is quite important in sound pictures. All noises that can be avoided in the original scene are avoided because they are usually reproduced in exaggerated importance. That is the very nature of binaural loss, which we must compensate.

SOUND AND SCENE GEOGRAPHY

We have some interesting geographical uses of sound. The geography of scenes can be tied together by handling of the sound effects. Take a simple little scene of a man leaving a lake. We will probably have to do some fre-

quency correcting in that scene, as there were some frogs croaking in that lake. We can cut the scene to the man walking up the steps of a little cottage or house. If we carry that frog croaking over to the scene of the little house it means that the house is near the lake. Suppose we shift the next scene to an elevated train. Naturally, one would expect that to be in a large city, and would not expect the elevated train to be right near the lake. We could not have the frogs croaking in the elevated-train scene. Many of those things are not put in there to be heard, but when we do hear the frogs croaking we know that the house is near the lake. We do not have to explain how the man got to the house. That will give just a little idea of the technique of sound in pictures. We utilize that effect work to get the audience's mind on the geography, the timing of the scene, and many of those things they do not hear.

Take the case of an orchestra in a restaurant. We will show the geography of the restaurant in a long shot. The orchestra will be quite full. Two principals may walk into the scene and start to talk. We drop that orchestra way down. We have a re-recording of that low orchestra music the moment the principals start to talk. You will not even notice that the orchestra has been lowered because we have switched your attention to the two people. You do that in actual life. The attention factor of the orchestra would have dropped 30 or 40 per cent the moment you started to listen to these two people so we just dropped the orchestra the moment they uttered a word. You go right through the scene without even noticing it.

As I have gone along I realize that I have not covered the entire subject of modern motion-picture technology, but I hope that I have covered some points that will be of most interest. As to the question of people in the studio, it is usually thought that the actors are the most numerous and, of course, the most important. In our studio we have some 4,000 employees, and I think that only about 200 of those are actually actors. When the whole gang gets going down the street to get something to eat you can hardly find an actor.

Combination Lighting Designed for Art Gallery

MASTERPIECES of famous artists in the Carnegie Institute's gallery *A* in Pittsburgh, Pa., now can be seen indoors just as the artists painted them, and many people for the first time are seeing parts of famous paintings which heretofore were not discernible. This is the result of a new system of lighting specially designed by Richard C. Engelken (M'33) well-known lighting consultant, and manufactured by Westinghouse. Because oldentime artists painted under natural daylight, paintings viewed under incandescent electric lighting are not seen in their true colors, and detail in dark spaces in the paintings is not discernible. By means of a special combination of 220 incandescent and 206 fluorescent lamps, the 112-foot long gallery *A* is lighted with an illumination nearly identical with the natural daylight by which most painters produced their works.

Lighting on the paintings is approximately eight times as bright as in the center of the gallery. This creates light comparable with the most ideal condition for viewing a scene out of doors. This illumination is obtained from a completely luminous ceiling of heat-treated water-white glass, above which are mounted four continuous rows of fluorescent lighting units. The light from these lamps is mixed with that from the incandescent units, mounted above control lenses which form part of the glass ceiling, along the four walls of the gallery. To obtain correct color matching, the control lenses are treated to take advantage of the relatively small amount of blue and green emitted by incandescent lamps. By adjusting lamp angles and lenses, dark paintings have been toned up, and the brilliant ones toned down.

(Left) Mr. Engelken directs adjustment of combined fluorescent and incandescent unit; (below) light from both sources is matched and controlled by special lenses in the ceiling units

Engineering Training for National Defense in the United States

A. A. POTTER

Leaders in the engineering profession and in the Army and Navy agree that the engineering colleges of the United States should maintain strong educational programs and increase their research efforts, in addition to making special facilities available for emergency training, according to this distinguished educator and consultant on the Government's program.

THE United States of America has set out upon an armament program which has as its objective the doubling of its Navy and the quintupling of its Army, in addition to large quantities of armaments for Great Britain. All facilities are being mobilized to insure speed and efficiency in carrying out this program. It is realized that the production of modern mechanized armaments on the scale contemplated requires not only millions of people who are skilled as mechanics but also large numbers of engineers who are competent in a wide variety of technical and supervisory services. One out of every ten employees of the airplane industry must be an engineer, as 250,000 man-hours are required to design a modern military plane. It takes about 25,000 blueprints for the construction of a medium-sized tank, and a modern battleship costs $5,000,000 to $8,000,000 to design and involves drawings which weigh tons. Already an acute shortage of technical engineering talent exists in certain of the industries as well as in the Army and Navy. The airplane industry reports serious shortages in engineers who can design, test, and maintain airplanes. Needed also are thousands of additional engineers who are competent as designers of tools, dies, jigs; or in part analysis, shop layout, and cost estimates of labor and materials. Additional engineering inspectors are needed by industry as well as by the Army and Navy, with knowledge of materials, physical testing, X-ray inspection, radiographic technique, and explosives, and automotive and electric communication equipment. There is also a substantial shortage of machine designers, metallurgists, naval architects, and marine engineers. Besides the needs for technical engineering specialists, industry is confronted with a shortage of industrial engineers and engineering supervisors to speed up the production of equipment necessary to the present armament program—engineers who are familiar with industrial organization, time and motion study techniques, production control, material handling and storage, inventory, budgetary and accounting control, industrial safety, and industrial relations.

During the First World War the engineering schools of the United States were responsible for the major portion of the vocational training program for the United States Army. The vocational division of the Students' Army Training Corps was mainly concerned with the training of mechanics and little attention was given to defense training on the engineering-school level. During the past 23 years the United States Government has co-operated with the various states in the development of a nation-wide program of vocational education of less than college grade. As a result of this there are available in the United States over 1,000 public vocational schools with a plant valued at more than $1,000,000,000. The Congress of the United States of America has appropriated to the United States Office of Education for the present fiscal year, ending June 30, 1941, a total of $66,500,000 for a vocational education program of "less than college grade." This vocational education program is being administered in every state under the state board of vocational education and is carried on mainly in secondary schools and trade schools. Much of this program is concerned with supplementary evening courses for individuals now employed in industry. Pre-employment full-time courses are also administered to increase the supply of workers essential in the National Defense program. It is expected that during the present fiscal year the skills of more than 500,000 people will be increased through this vocational educational program of "less than college grade." No tuition is paid by those receiving instruction.

Engineering colleges realize that their greatest contribution to our armament program will come by undertaking the type of training for which they are best equipped, that is, training on the "engineering-school level," rather than vocational trade courses which ordinarily can be taught more effectively by trade and vocational schools. By college level is meant instruction comparable in difficulty and prerequisites with courses included in engineering curricula. The leaders in the engineering profession as well as in the Army and Navy are insistent that the engineering schools of the United States should maintain during the present emergency the strongest possible programs of undergraduate and graduate instruction and should increase their research efforts so that an adequate supply of well-trained and creative engineers is assured. It is felt, however, that many of our engineering schools have special facilities which may be utilized advantageously, without interrupting their regular programs, in making available to our defense industries and to our Army and Navy additional and more competent engineering specialists. Congress appropriated on October 9, 1940, to the United States Office of Education $9,000,000 (*EE, Dec. '40, p. 521–2; Feb. '41, p. 92–3*) to be used in reimbursing engineering schools up to June 30, 1941, for the administration of the following programs:

1. In-service training programs for the purpose of up-grading the

Address prepared for the annual meeting of the Engineering Institute of Canada, Hamilton, Ont., Canada.

A. A. POTTER is dean of the schools of engineering, Purdue University, Lafayette, Ind., and consultant and chairman of the advisory committee to the United States Office of Education on the engineering education program for National Defense.

engineers and supervisors now employed in industry. More than 50,000 of the engineering and supervisory staffs, employed in defense industries, are now enrolled, mainly outside of working hours, in classes which meet two or more times every week. Some of these classes are in the nature of refresher courses and cover subjects ordinarily given during the first three years of an engineering college curriculum. The majority, however, are enrolled in advanced classes in design and industrial engineering. Present indications are that this in-service training program will have to be greatly extended and enlarged during the next few months. Through this type of training engineering schools are in a position to speed up the armament program and to improve the product of defense industries without interrupting their regular collegiate engineering instruction on the campus.

2. Intensive resident programs of study are being set up for the benefit of commissioned officers of the Army and Navy and for those who are interested in preparing for the specialized engineering positions now open in the defense industries or in government employ under the regulations of the United States Civil Service Commission. These intensive courses are about three months in length and are open to those who have had some formal engineering education, usually about three years, and considerable experience. As a concrete illustration: The Air Corps of the United States Army has at present 50 cadets in each of two engineering schools who are being given an intensive three-month course in aerodynamics, airplane structures, airplane power plants, and airplane instruments. The majority of these cadets are engineering college graduates and are being prepared for commissions in the Air Corps of the United States Army as squadron engineering officers. It is expected that about 600 such squadron officers will be trained during the next few months. Due to the fact that nearly all the engineering college graduates are well placed in industry, the resident intensive program is not developing as rapidly as is the in-service program. It is expected, however, that at least 10,000 will be benefitted by this program between now and June 30, 1941.

Up to March 8, 1941, a total of 684 engineering defense training programs had been approved to be administered by 128 engineering colleges in most of the United States, the District of Columbia, and Puerto Rico.

The engineering defense training program is administered under the chief of the division of higher education of the United States Office of Education, Doctor Fred J. Kelly, with Dean R. A. Seaton on leave from Kansas State College as director of the program. An advisory committee on engineering defense training, which is representative of the engineering and engineering teaching professions, has been set up by the United States Office of Education to aid in formulating policies for the in-service and intensive training programs on the engineering-school level. Contacts between Washington and the engineering colleges and the defense industries are maintained by 22 regional advisers appointed by the United States Office of Education.

Present world conditions demand that technology operates at full speed. The engineer's initiative as well as his creative and managerial talents must be used most extensively in the gigantic armament program of the United States of America. It is hoped that the in-service and preservice intensive programs on the engineering-school level described will prove helpful in meeting the present acute shortage of engineering specialists and will also improve the competence of employed engineers and engineering supervisors so that they may be in a position to design and build better armaments in the shortest possible time.

More Baseball Fields Lighted

GRIFFITH STADIUM in Washington, D. C., will be the ninth major league baseball park to be floodlighted, when the installation now ordered is completed. Eight towers, 150 feet high, will carry a total of 740 floodlights of 1,500 watts rating but operating at 10 volts overvoltage so as to give a light output about 35 per cent above normal rating, with only 16 per cent increase of wattage.

St. Louis, Mo., and Pittsburgh, Pa., joined the night baseball parade during 1940. Sportsman's Field, the home of the St. Louis Cardinals and Browns, is now illuminated with 754 floodlights of 1,500 watts each, mounted on eight steel towers, in banks more than 100 feet above the ground. Forbes Field in Pittsburgh became the brightest lighted park in the United States when its 864 floodlights supplying 210,000,000 candlepower were installed.

The accompanying illustration shows one of the floodlight towers at the Polo Grounds, home field of the New York Giants, also floodlighted during 1940. This tower also is typical of those installed at other fields. A total of 836 floodlights on eight towers 150 feet above the ground supply 200,000,000 candlepower for the Polo Grounds. The illumination level is greatest at the infield, because of the concentration of play.

Institute Activities

Defense Insurance vs. Hysteria

Some Suggestions as to Ways for Engineers to Aid the Defense Program — A Message From President Sorensen

WHEN the second 1940–41 AIEE presidential tour ended February 17th, its president in fulfillment of the business of his office had travelled 27,600 miles, visited 24 Sections and 16 Branches, attended 4 conventions, and addressed more than 50 gatherings; whereupon he said to himself: "I shall spend the next four weeks at my beloved and somewhat neglected California Institute of Technology teaching classes and contributing my bit to the research problems in which I have an interest."

In these days man proposes but Defense disposes. Only ten short days, used in "catching up" the things to be done that had accumulated while attending the highly successful winter convention and making the second tour of Section visits, have elapsed and as we begin this message, we are reluctantly speeding eastward across the continent (a round trip of 5,380 miles) for the purpose of spending two days working as a member of the Society for the Promotion of Engineering Education committee on acceleration of regular undergraduate engineering programs. That committee was appointed to study data submitted by the engineering colleges of the United States and prepare a report which SPEE may use to inform the advisory committee on engineering defense training of the United States Office of Education regarding "the feasibility and advisability of accelerating the regular undergraduate programs of the engineering colleges of the country."

The members of the special committee are:

Dean I. C. Crawford, University of Michigan
President H. T. Heald, Illinois Institute of Technology
Dean C. E. MacQuigg, Ohio State University
Dean E. L. Moreland, Massachusetts Institute of Technology
Dr. R. W. Sorensen, California Institute of Technology
Dean F. L. Wilkinson, University of Louisville
President D. B. Prentice, Rose Polytechnic Institute, *exoficio*
Secretary F. L. Bishop, University of Pittsburgh, *exoficio*

The task responsible for this journey and the labor that must be done free of charge by the eight busy members of the committee impel us to ask some questions: "Is all this commotion in our homeland a hysteria produced by echos from the battlefields of Europe, Africa, and Asia, or is it a sane measure of insurance against sparks flying from that dastardly man-made hell that are falling hot and thick all over the world? Are we so vulnerable that some of those sparks falling in America may grow into damaging conflagrations spreading from within to cause destruction? Are we sufficiently safeguarded by our Defense preparations to repel the fiery blasts back of the sparks that may sweep across land and sea or sail en masse through the heavens to engulf us from without?"

For our part, we are of the opinion that the time has arrived when actions of Defense or protection against slavery by dictatorship are not a sign of hysteria, but rather a new form of insurance as logical and essential for our protection as are the less expensive common forms of insurance which we all use as a matter of course. If we, the citizens of the United States, wish to maintain the right to determine when we will or will not go to war, it is obvious that until such time as nations will respect agreements we must have the power to make those who would destroy the rights of individual freedom respect our ability to defend those rights.

WE MUST NOT FORGET that the liberty we hold so dear can be continued only if we are willing to pay as much in time, energy, and the measure of the sweat of our labors that we call money, as those who are trying to destroy the freedom of the individual are willing to pay for its destruction.

At a price, our fathers bought the liberty for which democracy stands and have maintained it in America for more than one and one-half centuries.

As these lines are written, I glance from time to time through the windows of a speeding train at fertile fields that within my own memory were buffalo grazing grounds covered with sod so tough that every foot of furrow turned was a tussle with nature. Indeed, with my own eyes I saw my father, an immigrant from Norway, patiently turn over that sod with a plow drawn by oxen. (Horses could not do the job, and tractors were unknown as substitutes for draft animals.) He, and the thousands of others who thus labored to advance the land of America from the Atlantic to the Pacific, did not seek a life of ease, but rather sought a life of freedom for us, their children.

How well they builded! We their children enjoy a freedom and standard of living unequalled by the citizens of any other nation recorded in the pages of history. We can look all the world in the face and say "We are freeborn"; and may God grant that our children and children's children may have the right to make the same declaration for a thousand years to come.

Engineers have had a large part in making possible those very high standards of living, because they have created the machines that

Station 5 of the Rochester Gas and Electric Corporation, on the Lower Falls of the Genesee River at Rochester, N. Y. Details and tentative program of the North Eastern District meeting to be held at Rochester April 30–May 2, 1941, appear on pages 177–8

have released men from living by strength of muscle alone.

We must not forget that in so doing they have annihilated many of the influences that time and space had upon man's activities. Engineers made it possible for us to leave our office in Pasadena, California; travel 5,380 miles enjoying a good sleep every night; spend two nights in the luxury of a fine University Club and do two long days' work, in Pittsburgh; and return to the Pasadena office in less than a week of elapsed time—all without at any time experiencing the inconvenience of so much as a delayed meal, an uncomfortable chair or bed, or even an undesirable room temperature in which to rest or work. Indeed, men can now travel comfortably around the world in much less time than men could, at the time the United States was formed, cross the area comprising the original thirteen colonies in a manner that we now would consider a great hardship even though it was the finest type of transportation available at the time. Engineers have made it possible for us to have instant communication with those we love and with our business associates throughout the length and breadth of the United States, or even beyond those limits, if those we would like to reach are not in countries at war or dominated by dictators.

Yes, engineers did all this by "breaking sod" in the realms of time, space, invention, and science—even as our fathers, the so-called pioneers of America, tamed the wilderness of land and sea. Engineers are not knowingly going to stand by and see the machines they have made prostituted by dictators who conquer countries by force and lash the citizens of their own and the captured countries into slavery. This present slavery is ruled by dictators who, for appeasement of the public, are surrounded by puppet executives that, like Charley McCarthy, may be merely $500,000 chunks of wood so long as they can be clad in fine raiment and are admired by the masses that watch them perform. When the dictators can find no further use for them these puppets become just sticks in a woodpile ready to be burned to ashes by the first hobo who may find need for a bit of wood for a little fire to make a cup of coffee.

In 1936, when engineers from 58 countries made a 9,000-mile World Power Conference tour around the United States, the German engineers on that tour said to us one night in a quiet conversation: "You are a prosperous people because you have such a large area under one government. We Europeans must organize our many little countries into a large country under one government and that government must be Germany!" Did these German engineers know that their Germany was rapidly becoming a slave nation in the hands of a dictator and his puppets? Have the ideals of the German engineers become so distorted that they now willingly use their high mentality and almost unsurpassed ability as engineers to provide by the thousands the devilish weapons of destruction now being used so ruthlessly against their fellowmen—noncombatant citizens, women and children as well as men—or are they in the hands of Hitler and his Nazis as helpless as Charley McCarthy sitting on Edgar Bergen's knee? Indeed, perhaps we well may ask: Is Hitler just a Charley McCarthy clowning for his fine clothes and 75 cents a week for the amusement of the citizens of Germany, while the real group responsible for all Europe's troubles manipulates the dummy?

On that World Power Conference tour, during a discussion relating to the war then raging in Spain, some Greek and Spanish members of the party said the only way to stop the spread of that war was for England to step in and call a halt. Did the English engineer, who answered that comment by saying "England is tired of policing Europe" foresee at all what has since come to pass? Is it probable that he now would make such a comment? Or is he, like every other Englishman, at the present time busily engaged in saving by every means within his power what England stands for—liberty and freedom for the individual? Would that English engineer now say "England is tired of policing Europe" and stop there? Or would he add to that statement: ". . . but it must be done, and if England cannot do it alone, or even if she can, would it not be much better to have a democratic United Nations of the World, since there already exists a dictator United Nations of the World?" Yes, let us have a democratic Nations of the World, growing rapidly as nation after nation is added, not because forced by conquest of arms to do so, but because to balance the dictator group the democracies also must organize into a group, rather than try to act singly as individual nations. What would Poland, Holland, Denmark, and Norway do if, knowing what the citizens of those countries now know, they could return to conditions extant in 1936? What would England and the United States do, if knowing what is known today, their citizens could reconsider the problems which faced them in 1936?

When the United States was formed, the problems faced by the original 13 colonies must have appeared as complicated to the citizens of those colonies as do the problems facing the nations of today. Yet at a time when it took much longer to assemble and communicate than it does at present, those 13 colonies formed the United States of America and developed together a security and prosperity for their citizens that never could have been attained by the colonies as 13 separate nations. Yes, the world is now small, as is known to everyone who can read and write or listen to a radio.

Every engineer in the United States should heed well the signs of the times as he plans to serve his country.

Shall that service be rendered blindly or under compulsion, as our European brother engineers serve (for I cannot think their scientific minds believe in dictatorship and slavery though its reward may be a mess of pottage); or are engineers ready to have a voice in determining how the machines they have created shall be used? The question today is not whether there is going to be a United Nations of Europe or perhaps of the World; the question of today is whether there is going to be a democratic United States of the World to balance the dictator United States of the World?

We are helping England, the other great English-speaking unit of government, to stave off destruction in order that America may not be left the sole policing force available for its self protection. Americans who have lived in China for a generation say that if England falls, China will fall. If England and China fall, what would happen to the many countries now unprepared to resist an onslaught by the dictator United States of the World, already tremendously large and daily growing larger? Would America be left to try to police alone the world for a time? Would her citizens become tired of the job in numbers large enough to have us sooner or later fight the same kind of a battle England now is fighting?

But this story grows long because the mission which called us to make this trip has given us opportunity to formulate some of the ideas the present world crises—our present American crisis, if you please—have brought about.

The committee to consider the acceleration of undergraduate engineering courses, mentioned earlier in this message, has met and analyzed data submitted by almost every engineering college in the United States. From these data it is obvious that every one of these colleges and all their faculties favor the greatest haste possible in carrying out the Defense measures now under way. To aid in those measures, the engineering colleges are willing to accelerate the regular engineering courses, even though any such acceleration means a sacrifice of standards of engineering education.

The immediate logical move toward such acceleration is that of moving forward the time of graduation for the engineers of the class of 1942 (the present junior class) by having them continue through the coming summer.

Any accelerated program of engineering education, to be effective, should be an integral part of a completely co-ordinated program of placement for engineers on the part of the Army, the Navy, industry, local draft boards, the public, and all engineers. Such a co-ordinated program should provide for:

1. The deferment of induction of engineering students (those carrying full-course programs) into military service until after the completion of their college courses;

2. The use of engineers only for work where engineering training is required. This feature may call for the transfer to engineering work of engineers now engaged in work that requires very little engineering, and the filling of the positions now held by such engineers with men having less technical training;

3. The release from Army and Navy service of all engineers not engaged in engineering work, and their placement where engineers are needed in essential industries;

4. A very careful consideration by all draft boards of the qualifications of engineers, together with the needs of Army, Navy, industry, and engineering schools for engineers with special training, in order that draft classifications may be so made as to promote maximum efficiency in the Defense Program.

The Sections, Branches, and members of AIEE can help in this great program of trying to have the 12,000 to 14,000 engineers graduating in 1941 satisfy a demand for at least four times that number of young engineers, by becoming acquainted with the work being done by the engineers of their locality and helping to correlate the Defense Program's demand for engineers with the available supply of men qualified to do the work. This may mean arranging a plan

of co-operation with employment agencies, placement offices of colleges, and industries, or even of establishing in connection with present Section activities a clearing house for registration of engineers and of the positions requiring engineers. Another service that may be rendered by AIEE members is that of assisting the local draft boards whenever possible by providing them with factual information regarding the places where engineers are needed in numbers greater than the available supply.

North Eastern District Meeting to Be Held in Rochester, April 30-May 2

THE North Eastern District meeting will be held in Rochester, N. Y., April 30 to May 2, 1941, with headquarters at the Sagamore Hotel. An interesting and varied program of technical sessions, inspection trips, entertainment, and special features has been arranged.

TECHNICAL SESSIONS

The program includes seven sessions to be held during the mornings and afternoons. Four of these will be devoted to the presentation of technical papers, while a fifth will include addresses by well-known speakers designed to interest many members. In two others papers will be presented by students.

STUDENT BRANCH CONVENTION

Enrolled students are invited to attend the Student Branch convention. Two parallel sessions devoted to technical papers will take place on Friday morning, with the usual counselors' luncheon at noon. The executive committee of the North Eastern District has made the usual grant for prizes and travel allowance. The final list of paper titles and names of authors is scheduled to reach all Branches in the District about two weeks prior to the meeting.

ENTERTAINMENT

A stag smoker will be held on Wednesday evening, April 30, which will include a varied program of entertainment and a buffet supper. Tickets for the event may be secured at the registration desk.

An informal banquet will be held on Thursday, May 1, at the Rochester Club, located directly opposite headquarters. Doctor R. W. Sorensen, president, AIEE, will address the members and guests, and Doctor Alan Valentine, president of the University of Rochester, will be the principal speaker. Everett S. Lee, vice-president, North Eastern District, will act as toastmaster. Tickets may be reserved in advance and will be available at the registration desk.

Entertainment for women guests will be provided in the form of visits to interesting

Tentative Rochester Program

Wednesday, April 30

9:00 a.m. Registration

10:00 a.m. Communication

H. E. Gordon presiding

Address of welcome. Everett S. Lee, vice-president, North Eastern District

Address, "Communications in National Defense." Doctor R. H. Manson, vice-president, Stromberg-Carlson Telephone Manufacturing Company

Address, "Unusual Applications of Electrical-Engineering Principles in Television." Doctor George R. Town, engineer, Stromberg-Carlson Telephone Manufacturing Company

Address, "High-Speed Photography with the Edgerton Lamp." Ford M. Brown, research laboratories, Eastman Kodak Company

Address, "Some Considerations in the Design of Electromagnetic Relays for Use in Telephone Systems." Oliver L. Angevine, Jr., engineer, Stromberg-Carlson Telephone Manufacturing Company

2:00 p.m. Central Stations

E. K. Huntington presiding

Address. Herman Russell, president, Rochester Gas and Electric Corporation

41-84. METHODS OF DETERMINING NATURAL FREQUENCIES IN COILS AND WINDINGS. **L. V. Bewley, J. H. Hagenguth, and F. R. Jackson, Jr.,** General Electric Company

41-90-ACO.* SIMPLIFIED METHODS OF CALCULATION FOR LONG TRANSMISSION LINES. **E. E. George,** Ebasco Services, Inc.

41-85. SURGE CHARACTERISTICS OF TWO-WINDING TRANSFORMERS. **Reinhold Rüdenberg,** Harvard University

8:00 p.m. Stag Smoker

Thursday, May 1

10:00 a.m. General Session

Colonel Carey H. Brown presiding

Address, "Priorities in Men." Doctor Harvey N. Davis, president, Stevens Institute of Technology

● PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in this program may be obtained as noted in the following paragraphs.

● ABSTRACTS of papers appear on pages 179-80 of this issue of Electrical Engineering.

● PRICES and instructions for securing advance copies of these papers accompany the abstracts. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

● COUPON books in $5.00 denominations are available for those who may wish this convenient form of remittance.

● ALL PAPERS regularly approved by the technical program committee ultimately will be published in Transactions, many will appear also in Electrical Engineering.

41-93-ACO.* RADIO NAVIGATION AND AN OMNIDIRECTIONAL RADIO RANGE. **David G. C. Luck,** RCA Manufacturing Company, Inc.

Presentation of awards

2:00 p.m. Selected Subjects

H. H. Race presiding

Address, "The Engineering Societies and National Defense." H. H. Henline, national secretary, AIEE

41-92. PHOTOGRAPHIC STUDY OF A-C ARCS IN FLOWING LIQUIDS. **J. Slepian and T. E. Browne, Jr.,** Westinghouse Electric and Manufacturing Company

41-89. THE DETERMINATION OF MAGNITUDE AND PHASE ANGLE OF ELECTRICAL QUANTITIES. **Eric A. Walker,** University of Connecticut

41-91. THE DIELECTRIC STRENGTH OF GLASS—AN ENGINEERING VIEWPOINT. **E. B. Shand,** Corning Glass Works

7:00 p.m. Banquet

Everett S. Lee, vice-president North Eastern District, presiding

Welcome to members, Doctor R. W. Sorensen, president, AIEE

Address, Doctor Alan Valentine, president, University of Rochester

Friday, May 2

8:00 a.m. Student Sessions

E. A. Walker presiding

Selected subjects

12:00 noon Branch Counselors' Luncheon

2:00 p.m. Industrial Applications

J. Leo Scanlon presiding

41-86. THEORY OF THE BRUSH-SHIFTING A-C MOTOR—PART I. **A. G. Conrad, F. Zweig, and J. G. Clarke,** Yale University

41-87. THEORY OF THE BRUSH-SHIFTING A-C MOTOR—PART II, CHARACTERISTICS. **A. G. Conrad, F. Zweig, and J. G. Clarke,** Yale University

41-83. OVERVOLTAGES IN POLYPHASE INDUCTION MOTORS DURING SINGLE-PHASE OPERATION. **C. Macmillan and G. E. Carter,** General Electric Company

41-82. POWER SUPPLY FOR RESISTANCE-WELDING MACHINES—III, FACTORY WIRING FOR RESISTANCE WELDERS. Subcommittee on Power Supply for Welding Operations, L. W. Clark, chairman. Presentation by J. D. Wright, chairman, committee on electric welding

41-88. AMPERE-SQUARED-SECOND RECORDER. **T. A. Rich,** General Electric Company

*ACO: Advance Copies Only available; not intended for publication in TRANSACTIONS.

Part of Rochester's industrial section, seen from the air

points in the city as well as a schedule of luncheons and dinners.

INSPECTION TRIPS

The requirements of national defense make it impracticable at this time to present a regular schedule of inspection trips. However, arrangements will be made by the committee to provide for visits to industrial plants and utility stations wherever feasible. A program will be available at the registration desk.

COMMITTEES

District meeting: Everett S. Lee, vice-president, North Eastern District; R. D. Lorraine, secretary-treasurer, North Eastern District; A. G. Conrad, H. D. Griffith, O. E. Sawyer, M. G. Northrup, E. A. Gruppe, C. E. Tuites, W. F. Cotter.

Technical program: J. H. Rogers, *chairman;* A. G. Schifino, G. R. Town, C. L. Smith, R. C. Keberle, E. M. Morecock, F. C. Starr, W. C. Winterroth, A. V. Dasburg, Oliver L. Angevine, Jr.

Transportation and trips: W. Criley, *chairman;* Oliver L. Angevine, Jr., C. S. Chase, W. D. Halles, E. K. Huntington, Lee McCanne, F. McVittie, Brian O'Brien.

Hotels and registration: O. Laurence Angevine, *chairman;* A. F. Luckett, R. G. Burns, A. F. Martin, R. A. Whitford, A. E. Schell, R. H. Rankin.

Entertainment and banquet: R. A. Whitford, *chairman;* C. G. Plomasen, W. J. Scanlan, C. A. James, J. H. Taber, G. H. Haupt.

Finance: H. J. Klumb, *chairman;* C. F. Harris, *treasurer;* O. Laurence Angevine.

Publicity: E. B. Kempster, *chairman;* O. Laurence Angevine, J. A. Glenger, G. E. Baker, H. J. Genthner, J. H. Levis, Jr.

Reception: C. E. Tuites, *chairman;* L. A. Waasdorp, C. S. Barrow, E. R. Crofts, W. K. Howe, Colonel C. H. Brown, L. B. Swift, J. W. Morrison, H. H. Sullivan, T. L. Lee, Mark Ellingson, J. H. Snyder.

Women's entertainment: Mrs. C. L. Smith, *chairman;* Mrs. O. Laurence Angevine, Mrs. J. H. Rogers, Mrs. C. F. Harris, Mrs. C. E. Tuites, Mrs. B. M. Werly, Mrs. R. A. Whitford, Mrs. W. F. Cotter.

Student sessions: E. A. Walker, District Branch counselor.

National • • • •

Summer Convention Committee Plans Unusual Program

Plans for the 1941 AIEE summer convention, to be held at the Royal York Hotel, Toronto, Canada, June 16–20, are already taking definite shape. The summer convention committee, which has been meeting regularly for several months now, is working on the assumption that this year's gathering will set a new record for attendance.

The committee points to many factors that make Toronto a unique convention city of special interest to American visitors in this particular year. Not the least of these factors is the location of the city in the heart of Canada's industrial region. Canada is a nation at war, and convention-attenders will see signs of war activity everywhere—industries working long hours; airmen, soldiers, and sailors on the streets. Members and guests will visit plants in which production has been rising steeply since September 1939.

Despite the fact that Canada is at war, United States citizens may enter the country as easily and move about as freely as ever (*EE, March '41, p. 134*).

Among the factors expected to increase attendance is the newly completed Queen Elizabeth Way—the superhighway from Niagara Falls to Toronto. Many probably will travel this highway if only to see the longest stretch of highway lighting in the world. By June the lighting will be completed from one end to the other.

The Royal York Hotel, Toronto, summer convention headquarters, is said to be the largest hotel in the British empire

Future AIEE Meetings

North Eastern District Meeting
Rochester, N. Y., April 30–May 2, 1941

Summer Convention
Toronto, Canada, June 16–20, 1941

Pacific Coast Convention
Yellowstone National Park, August 27–29, 1941

South West District Meeting
St. Louis, Mo., October 8–10, 1941

Southern District Meeting
New Orleans, La., December 3–5, 1941

Winter Convention
New York, N. Y., January 26–30, 1942

Membership—

Mr. Institute Member:

What the future holds in store for us may be in doubt, but one thing is certain, the electrical engineer needs the Institute today more than ever before, as it is the national organization of his profession. It follows that the Institute needs the membership of all engineers qualified for membership and it is our duty to bring the advantages of membership to their attention.

About 800 of your fellow members have volunteered and are devoting their time and energy to the membership work of the Institute. But if they are to succeed in a big way you must help them to locate eligible prospects. That is why we ask you to send in their names to your Section membership committee.

O. C. Brill

Chairman, National Membership Committee

When Canada's natural scenic beauty and facilities for sport are also considered, the convention committee's prophecy of a record attendance seems only reasonable. With such an attendance in mind, the committee is gathering outstanding technical papers and laying plans for several novel entertainment and sports features.

Branch • • • •

University of Connecticut Branch Holds Installation Meeting

Authorized by the AIEE board of directors at its meeting January 30, 1941 during the winter convention, the University of Connecticut Branch held its first meeting at Storrs, Conn., February 20, 1941. Doctor E. A. Walker, associate professor of electrical engineering, University of Connecticut, and chairman of the District 1 committee on student activities, was named counselor of the new Branch. The officers are Arthur Eckels, chairman; John Cooledge, vice-chairman; Anthony Tiezzi, secretary-treasurer.

Principal speaker was E. S. Lee, General Electric Company, vice-president of the North Eastern District, who talked on "The Contributions of the Electrical Engineer". Doctor Charles F. Scott, founder of Student Branches, sent best wishes for the success of the Branch. Guests present included:

R. G. Warner, New Haven, AIEE director; W. B. Hall, counselor, and James Hasney, chairman, Rhode Island State College Branch; Victor Siegfried, counselor, and Peter Jaremko, chairman, Worcester Polytechnic Institute Branch; A. G. Conrad, counselor, Yale University Branch.

Section • • • •

Pittsburgh Section Hears Talk on Submarines

At a joint technical meeting of the AIEE Pittsburgh Section and the electrical section of the Engineers' Society of Western Pennsylvania, February 25, 1941, Lieutenant Commander J. P. Thew, in command of inspection at Cleveland Diesel-engine division, General Motors Corporation, spoke on "The Submarine, Its Powering, Maneuvering, and Control". Motion pictures illustrated the address, at which about 460 were present.

Pageant on Light and Civilization Presented at Lynn

Sponsored by the public utilities committee of the AIEE Lynn Section and officials of the Lynn Gas and Electric Company, a pageant, "The Torch of Civilization," was presented at Lynn, Mass., February 11, 1941, to an audience of about 1,200, including members of the Lynn Section, the New England section of the Illuminating Engineering Society, special guests, and others. The pageant, presented on the 94th anniversary of Edison's birth, depicted the development of light from the pre-Christian era to the present, with one scene showing Edison's discovery of the incandescent lamp. Except for the title, which was used by permission of Doctor Matthew Luckeish (A'11, M'15) General Electric Company, author of the recent book of that name, the production was an original rendering of a technical message in dramatic form. Members of the Lynn Gas and Electric Company Players constituted the cast; A. B. Whitehouse (A'39) Lynn Gas and Electric Company, was in charge of production, assisted by Moorhead Wright, Jr., General Electric Company, and J. A. Melanson, Lynn Gas and Electric Company.

Officials of the Lynn Gas and Electric Company sponsoring the pageant "The Torch of Civilization" included (top row, left to right) A. B. Whitehouse (A'39) superintendent, electric distribution; E. W. Allen, merchandise manager; J. W. Lingary (M'32) superintendent, electric plant; I. A. Patten (A'28) general superintendent, electric department; (second row, left to right) F. M. Kelley, president; J. A. Cook (A'13, F'30) general manager; E. H. Fraser, treasurer

New York Section and IES Hold Joint Meeting on Protective Lighting

Meeting jointly on February 25, 1941, the New York Sections of the AIEE and the Illuminating Engineering Society heard A. H. Crowl, special agent, Federal Bureau of Investigation, and D. H. Tuck, electrical engineer, Hollophane Company, discuss the protection of American industry. Declaring that there are no organized groups of saboteurs operating in the United States, Mr. Crowl blamed disregard of safety rules for many of the accidents attributed to sabotage, and emphasized illumination, along with proper fencing and screening, as most important in preventing spies from entering industrial plants. Mr. Tuck discussed various aspects of protective lighting in detail.

Abstracts • • •

TECHNICAL PAPERS are previewed in this section as they become available in advance pamphlet form. Copies may be obtained by mail by remitting price indicated to the AIEE order department, 33 West 39th Street, New York, N. Y., or at five cents less per copy if purchased at AIEE headquarters or at AIEE convention or District-meeting registration desks.

The papers previewed in this issue will be presented at the North Eastern District meeting, Rochester, N. Y., April 30–May 2, 1941.

Air Transportation

41-93—ACO—New Method for Radio Guidance of Aircraft; *D. G. C. Luck. 25 cents by mail.* The problem of navigation and the means at hand for its solution are described. Some principles of radio direction finding are set forth and shown to lead to three main systems of use which are compared as to operating properties. The operation of a development of one system, giving direct omnidirectional bearing indications, is explained. Experimental omnidirectional range equipment is described. Finally, the actual use of the range in flight is explained and some results of flight tests of experimental omnidirectional ranges are presented as indicative of their present performance.

Basic Sciences

41-91—The Dielectric Strength of Glass—An Engineering Viewpoint; *E. B. Shand (M'29). 15 cents by mail.* Available data on the dielectric strength of glass show such wide variations that the insulation engineer is faced with a difficult problem in making applications of this material. A study has been made to correlate such data, both from the literature and from original sources, with the result that characteristic curves have been worked out for certain boundary conditions. There are a number of factors which influence the breakdown strength of insulation, one of the most important being the "edge effect", which may result from several specific causes. The use of oil as an ambient medium in making dielectric tests on a material such as glass produces a severe type of edge effect which may vitiate seriously the results obtained, so that adequate consideration must be given this matter. With the use of the characteristic breakdown curves and other information, the insulation engineer can make an intelligent approximation of the breakdown strength of glass under certain conditions which, if not of a high degree of accuracy, will give him a better perspective of the possibilities of this application of glass. Corresponding characteristic curves for porcelain of the same general form show several interesting comparisons.

Electric Welding

41-82—Power Supply for Resistance-Welding Machines—III. Factory Wiring for Resistance Welders; *Subcommittee on Power Supply for Welding Operations, Committee on Electric Welding, L. W. Clark (A'25), chairman. 15 cents by mail.* With more and more resistance welders being in-

stalled, particularly in conjunction with the new defense plants being built throughout the country, it is essential that an adequate power supply and proper factory wiring be provided in each case. Adequate electric service for large resistance welders is of greater moment and involves considerably more expense than the corresponding service for ordinary machine-tool installations, because of the low power factor and high single-phase kilovolt-ampere demand usually inherent with this type of equipment. The report shows how to lay out properly a plant distribution system for serving welders. It includes the necessary tables, charts, and illustrative examples of successfully operating installations, ranging in size from a small welding shop to a large manufacturing plant.

Electrical Machinery

41-84—Methods of Determining Natural Frequencies in Coils and Windings; *L. V. Bewley (M'37), J. H. Hagenguth (A'28), and F. R. Jackson, Jr. (A'40). 20 cents by mail.* A knowledge of the natural frequencies of transformer, reactor, and generator windings is essential for the determination of the transient response of such coils to lightning waves and switching surges, as well as for the calculation of the recovery characteristics of circuit breakers and expulsion gaps. Different testing methods have been employed to determine these natural frequencies, and usually it has been taken for granted that all these different testing procedures give results in substantial agreement. Recently, however, in a study of transformer transients it was found that several different methods of test failed to agree, and an investigation as to the cause of the discrepancies disclosed that all of these usual methods are not equally valid or reliable. It is the object of this paper to discuss various testing procedures, and to point out their theoretical limitations toward yielding the supposed information. The voltage distribution along the winding of a grounded-neutral transformer is discussed analytically and the basic equations developed. Results of voltage-distribution tests made by several methods are reported and compared.

41-86—Theory of the Brush-Shifting A-C Motor—I; *A. G. Conrad (M'40), F. Zweig, and J. G. Clarke (appl. pending). 20 cents by mail.* This is the first of a series of papers explaining the theory and the principles of operation of the brush-shifting a-c motor. Operation of the machine, either as a motor or a generator, is explained on the basis of the superposition of currents. The theory of the primary current loci is developed for both high-speed and low-speed adjustments. A method of determining the primary current loci from no-load measurements is presented. Experimental data have shown the theory to be valid.

41-87—Theory of the Brush-Shifting A-C Motor—II; *A. G. Conrad (M'40), F. Zweig, and J. G. Clarke (appl. pending). 15 cents by mail.* In the preceding paper (part I) of this series, a simple theory underlying the circle diagram of the brush-shifting a-c motor was presented. It is the purpose of this paper to advance this theory, and to show how it can be used to determine such quantities as efficiency, current, torque, and speed for different conditions of operation. The procedures outlined and explained have been checked experimentally, and found to be accurate for both high-speed and low-speed adjustments.

41-85—Surge Characteristics of Two-Winding Transformers; *Reinhold Rüdenberg (M'38). 25 cents by mail.* The paper shows the performance of transformers with two windings in rapid-transient state when surges develop in their conductors. The velocity of traveling waves along the wires of each of the windings is equal to the velocity of light in the dielectric space. The surge impedance of a winding is determined by the turn-density of the coils and the insulating distances and is in the range of 100 up to 20,000 ohms for power transformers of low voltage and high power up to high voltage and low power. On the arrival of a surge at the terminals, two different wave fields travel axially through the windings, a slow one coupled with the high-voltage coils and a fast one coupled with the low-voltage coils, both propagating with light-velocity helically in their respective windings. This mechanism effects a transmission of surge voltages between the two windings, entirely different from any steady-state transformation. The surge-coupling factors of the two windings are determined by the ratio of the insulating distances and by the square-root of the turn ratio.

Industrial Power Applications

41-83—Overvoltages in Polyphase Induction Motors During Single-Phase Operation; *C. Macmillan (M'35) and G. K. Carter (A'36). 20 cents by mail.* The object of the present paper is to record some of the results of tests and calculations undertaken to obtain more definite data on the factors which limit the safe and appropriate use of polyphase induction motors subject to temporary single-phase conditions. Calculations have been made, by several analytical methods, and some results plotted as graphs, which serve to explain the causes of the wave forms obtained in test and to illustrate the extent to which they can be duplicated by calculated results. From the comparison of calculated and test results, qualitative conclusions are drawn as to probable modifications introduced by factors which it is impossible to include in the theoretical analysis. Attention is called to the possibilities of dangerous excessive voltages in motor windings due to imperfections, defects, or inadequate maintenance of control equipment.

Instruments and Measurements

41-89—The Determination of Magnitude and Phase Angle of Electrical Quantities; *Eric A. Walker (A'34). 15 cents by mail.* Although the three-voltmeter method for measuring the relative magnitude and phase angle of two voltages or currents is well known, the use of vacuum-tube voltmeters, which draw negligible amounts of energy from the circuit, permits the use of the method for purposes that previously have not been considered. A further improvement of the scheme by balancing out one component of either voltage or current adds to the accuracy of the results. No attempt is made to extend the method to extremely small angles because the primary object is to produce a rugged, portable instrument for use in field tests. A further advantage is that because the method has one balancing element and an indicating instrument it is possible to follow rapid changes in power factor. The method is considered for two purposes; namely, the measurement of the capacitance and power factor of imperfect capacitors, and the measurement of the ratio and phase angle of current transformers.

41-88—Ampere-Squared-Second Recorder; *T. A. Rich. 15 cents by mail.* An instrument is described which records the ampere-squared-seconds in an electrical impulse of less than 0.5-second duration. A number of these have been used in resistance-welding applications to monitor the electrical variables and have contributed greatly to the uniformity of welds. The problem of indicating $^1/_{60}$-second impulses at the rate of 100 a minute with the same device that will integrate correctly a half-second impulse has been solved by the use of a moving element with an infinitely long natural period, combined with a supplementary circuit which returns the element to the starting position in a fraction of a second.

Protective Devices

41-92—Photographic Study of A-C Arcs in Flowing Liquids; *J. Slepian (F'27) and T. E. Browne (A'36). 15 cents by mail.* An apparatus has been constructed for so drawing an arc under oil or water that it can be subjected to a wide range of independently varied fluid velocities and pressures, and in which the arc and its associated gas bubble can be photographed at any point in the current cycle, more particularly at current zero. A large number of single and high-speed sequence photographs have been obtained of arc bubbles in various flow-directing structures. These have revealed, in general, that:

1. Displacement of the arc bubble by liquid dielectric follows arc extinction by an appreciable time lag;
2. Arc extinction is favored by the occurrence of a small bubble section at current zero;
3. The arc bubble undergoes an oscillatory variation in size and shape. This oscillation is at a considerably higher frequency than that of the current variation and is not synchronized with it;
4. For arcs in small bubbles near their critical conditions for extinction, there is no observable correlation at current zero between bubble appearance and tendency to re-ignite.

These observations are sharply at variance with a displacement or liquid-barrier theory of arc extinction, but suggest that the initial recovery of dielectric strength is by the arc bubble itself.

Transmission and Distribution

41-90—Simplified Methods of Calculation for Long Transmission Lines; *E. E. George (F'36). 25 cents by mail.* For lines around 300 miles in length, ordinary engineering accuracy in determining perform-

ance requires the use of the so-called "long-line" or "rigorous" methods of calculation. No matter whether graphic or analytic procedure is used, any "long-line" method requires the determination of certain supplementary factors prior to further calculation or graphic construction. It is essential to evaluate these factors with the greatest possible ease and accuracy. Conventional methods of determining θ, Z_0, A, B, C, and D (or their components) involve complex quantities and vector algebra. It is the purpose of this paper to describe a new and relatively simple method of calculating the above factors. A new and more useful line loss formula is also derived. In the method presented, complex or vector algebra is discarded and plain arithmetical formulas are used. There are no vector quantities or operations in these new formulas, since the scalar or absolute value of each quantity is used. Tables of plain circular and of plain hyperbolic functions are the only tables required.

Personal • • •

R. A. McCarty (A'16, M'32) manager of the steam division, Westinghouse Electric and Manufacturing Company, Philadelphia, Pa.; **F. D. Newbury** (A'07, F'21), manager of the emergency products division, Pittsburgh, Pa.; and **A. C. Streamer** (A'10), general manager of the East Pittsburgh division, recently have been elected vice-presidents of the company. Mr. McCarty was born at Mooresburg, Tenn., October 2, 1882, and graduated in electrical engineering at the University of Tennessee in 1903. He entered the student training course of the Westinghouse company the same year. He became successively design and section engineer in 1911, division engineer in 1927, and manager of the power engineering department in 1930. In 1935 he was made manager of the generator operating division, in 1937 manager of the small motor plant at Lima, Ohio, and in 1938 manager of the steam division. Mr. Newbury, who was born at Brooklyn, N. Y., June 9, 1880, received the degree of mechanical engineer from Cornell University in 1901 and also entered the student course at East Pittsburgh the year of his graduation. He became design engineer in 1903, section engineer in 1907, manager of power engineering department in 1911, and general manager of machinery engineering in 1931. He was appointed assistant to vice-president in 1935, dealing with budgets and administrative problems, and in 1937 was made economist of the company. He became manager of the new products division in 1938 and of the newly created emergency products division in 1940. He was a director of the Institute 1918–22. Mr. Streamer was born at Boulder, Colo., November 23, 1885, and received the degree of bachelor of science in electrical engineering from the University of Colorado in 1907. He entered the student course the same year and in 1920 was appointed assistant to the manager of the supply department. He became assistant sales director in 1924, sales manager of the diversified products division in 1931 and of the transportation division in 1933. He was appointed manager of the switchgear division in 1936 and general manager of the East Pittsburgh division in 1939.

A. N. Goldsmith (M'15, F'20) consulting industrial engineer, New York, N. Y., has been awarded the Medal of Honor of the Institute of Radio Engineers for 1941, "for his contributions to radio research, engineering, and commercial development, his leadership in standardization, and his unceasing devotion to the establishment and upbuilding of the Institute and its *Proceedings*." Born September 15, 1887, at New York, N. Y., he received the degrees of bachelor of science, 1907, from the College of the City of New York, doctor of philosophy, 1911, Columbia University, and the honorary degree of doctor of science from Lawrence College, 1935. He was a member of the faculty of the College of the City of New York 1911–26, becoming professor in charge of the electrical engineering department in 1916. He was consulting radio engineer for General Electric Company, 1916–18; director of the research department, Marconi Wireless Telegraph Company of America, 1917–19; director of research, chief broadcasting engineer, and vice-president, Radio Corporation of America, 1919–33. Since 1933 he has practiced as a consulting industrial engineer. He was for many years editor of the *Proceedings* of the IRE, of which he is a past president. He is also a past president of the Society of Motion Picture Engineers, and has been active in the work of the American Standards Association and the International Electrotechnical Commission. In 1940 he was honored as a "modern pioneer" by the National Association of Manufacturers. He is the author of books and articles on radio.

William Spraragen (A'17, M'26) technical secretary and editor, American Welding Society, New York, N. Y., has been awarded the Samuel Wylie Miller Medal of the society for 1940, "for his work on the welding research committee, as editor of the *Welding Journal*, and his part in promoting the ideals and work of the American Welding Society." A native (1895) of Warwick, N. Y., he received the degree of bachelor of engineering from Union College in 1916. He was employed by the General Electric Company, Acorn Insulated Wire Company, and Westinghouse Electric and Manufacturing Company before becoming instructor in electrical engineering, Oklahoma Agricultural and Mechanical College, Stillwater, in 1917. At this time he was assistant chairman of the electric welding research committee of the National Research Council and the Emergency Fleet Corporation. He was instructor in electrical engineering at the University of Washington, Seattle, 1918–19. In 1920 he became secretary of the NRC's division of engineering and industrial research, secretary of the American Bureau of Welding, and editor of the *Journal* of the American Welding Society continuing in the first two positions until 1934. He has been technical secretary of AWS since 1922, and is also secretary of the welding research committee of the Engineering Foundation. He is president of the Spraragen Engineering Corporation, New York.

Augustin Frigon (A'20) assistant general manager, Canadian Broadcasting Corporation, Montreal, has been selected as one of eight initial recipients of the Julian C. Smith Memorial Medal, established in memory of the late Julian C. Smith (A'88, M'99, F'13) and awarded by the Engineering Institute of Canada for outstanding service in the development of Canada. Mr. Frigon, a native (1888) of Montreal, received the degrees of bachelor of science and civil engineer, 1909, and electrical engineer, 1911, from the École Polytechnique, Montreal. From 1911 to 1914 he was electrical engineer for the Quebec Public Utilities Commission, and also carried on consulting practice. From 1910 to 1917 he headed the electrical-engineering laboratory at the École Polytechnique and in 1917 became head of the electrical-engineering department. He was commissariat general of Canada in Paris, France, 1920–22, and on his return to Montreal became director of the École Polytechnique and general director of technical education for the Province of Quebec, later becoming dean of the École Polytechnique. He was one of three engineers appointed to the Quebec Electricity Commission on its formation in 1936, and was made its president. Later in 1936 he was appointed assistant general manager of the newly formed Canadian Broadcasting Corporation.

R. W. Preston (A'23, M'28) appraisal engineer, Pacific Power and Light Company, Portland, Ore., has been elected president of the Professional Engineers of Oregon for 1941. **C. B. Carpenter** (A'23, M'34) engineer, Pacific Telephone and Telegraph Company, Portland, has been elected vice-president; **F. D. Weber** (A'09, M'30) chief electrical engineer, Oregon Insurance Rating Bureau, Portland, has been elected treasurer; and **O. L. LeFever** (A'10, M'21) general superintendent, Northwestern Electric Company, Portland, has been elected a trustee. The following Institute members were elected life members of the Professional Engineers of Oregon: **F. D. Weber** (A'09, M'30); **R. H. Dearborn** (A'07, F'30) dean of engineering, Oregon State College, Corvallis; **Walter Haynes** (A'35) dean of engineering, Oregon Institute of Technology, Portland; **L. T. Merwin** (A'10, F'33) president, Northwestern Electric Company, Portland; **F. H. Murphy** (A'07, F'30) consulting engineer, Portland General Electric Company, Portland; **H. A. Rands** (A'19) associate hydroelectric engineer, Portland District, United States Army Engineer Corps; **J. C. Stevens** (A'20, M'30) consulting engineer, Stevens and Koon, Portland.

Frederick Krug (A'17, F'36) formerly supervisor of southern properties, Montreal Engineering Company, Montreal, Quebec, Canada, has been appointed chief engineer of the company. He was born at New York, N. Y., October 12, 1893, and studied at Cooper Union, New Mexico School of Mines, and Massachusetts Institute of Technology. From 1917 to 1921 he was employed by the New York and Honduras Rosario Mining Company, San Juancito, Honduras, as assistant superintendent and superintendent of the electrical department.

His service with that company was interrupted by eight months as war instructor at Carnegie Institute of Technology, Pittsburgh, Pa., in 1918. In 1922 he became superintendent of hydroelectric plants at Comerio Falls, Puerto Rico, for the Porto Rico Railway, Light and Power Company, becoming superintendent of power production for that company in 1924, assistant to president, 1926, and vice-president and general manager, 1927. He continued in the last position until 1936 when he went to Montreal.

H. W. Clapp (A'08, M'13) general manager, aircraft construction, Department of Supply and Development, Commonwealth of Australia, Melbourne, was included in the Australian list of New Year Honors as Knight of the British Empire. Born in Melbourne, May 7, 1876, he spent five years with the Brisbane (Australia) Tramways Company before coming to the United States in 1902. He was employed by General Electric Company 1902–08, being engaged on several large railway electrifications. He then became assistant chief electrical engineer of the Southern Pacific Company, and later was first general superintendent and then general manager of the Columbus (Ohio) Railway, Power, and Light Company. He returned to Australia in 1920 as chairman of the Victorian Railways Commission, and took his present position in 1939.

W. H. Harrison (A'20, F'31) vice-president and chief engineer, American Telephone and Telegraph Company, has been assigned broader duties under the reorganization of the original national defense commission into the Office of Production Management. He heads one of three branches, that of shipbuilding, construction, and supplies, in the production division of OPM. His former assignment was co-ordinator of construction contracts. Mr. Harrison, who is a past president of the Institute, went to the defense commission in the summer of 1940. **Mark Eldredge** (A'14, F'33) who was director of the electrical division of the City of Memphis, Tenn., Light, Water, and Gas Division 1924–40, is now devoting full time also to the work of the Office of Production Management, Washington, D.C. He is a past vice-president and currently a director of AIEE.

Merrill De Merit (M'40) formerly general engineer, West Penn Power Company, Pittsburgh, Pa., has been appointed chief power engineer, Tennessee Valley Authority, Chattanooga, Tenn. He received the degree of bachelor of science in electrical engineering from the University of Wisconsin in 1914. He was engineer in the distribution engineering department of the Detroit (Mich.) Edison Company for about four years before going with the West Penn Power Company in 1922 as distribution engineer. He spent some time as assistant to the president on economic studies, and from 1929 to 1935 was assistant to the chief engineer of the West Penn Electric Company. He had been general and planning engineer of the former company since 1935.

M. E. Strieby (M'22) formerly high-frequency engineer, transmission development department, Bell Telephone Laboratories, New York, N. Y., has been appointed transmission engineer, long lines department, American Telephone and Telegraph Company, New York. He was transferred to the Laboratories in 1929 from the department of development and research of the American Telephone and Telegraph Company, where he had been employed since 1919. **J. F. Wentz** (A'24) engineer in charge of line engineering and measurements, transmission development department, becomes high-frequency engineer. He has been with Bell Laboratories and Western Electric Company since 1919.

R. E. Doherty (A'16, F'39) has been appointed as one of nine men to constitute a new agency of the Office of Production Management—the Production Planning Board—which is supposed to serve the double-barrel purpose of centralized planning of the current defense program and long-range planning for the inevitable future. Doctor Doherty, president of Carnegie Institute of Technology, and chairman of Engineers' Council of Professional Development, long has been active in AIEE industrial and educational circles. He is a representative of United States education on the new board.

F. L. Snyder (A'34) formerly section engineer, Westinghouse Electric and Manufacturing Company, Sharon, Pa., has been appointed manager of insulator and regulator engineering, transformer division, Sharon. **W. A. Sumner** (A'30) formerly section engineer in charge of small distribution transformer design, has been made manager of distribution transformer engineering in the same division. **C. W. Diehl** (A'34, M'39) formerly general foreman, has been made supervisor of quality control, and **A. D. Forbes** (A'32) has been appointed development section engineer, both in the transformer division.

H. S. Hubbard (A'23, M'35) designing engineer, General Electric Company, Pittsfield, Mass., received a Charles A. Coffin Foundation award for 1940 for the development and design of a 1,400,000-volt d-c generator to provide power for an X-ray tube used by the National Bureau of Standards. The awards are presented annually to General Electric employees for outstanding contributions to the progress of the company and to the electrical arts. Mr. Coffin was graduated from Pratt Institute in 1915 as an industrial electrical engineer. He has been with General Electric since 1920.

E. S. McConnell (A'29, M'36) has been appointed engineer on the staff of the Edison Electric Institute, New York, N. Y. He was electrical engineer with the Anaconda Wire and Cable Company, Hastings-on-Hudson, N. Y., from 1928 to 1937, when he received a leave of absence to serve the Copper Wire Engineering Association, Washington, D. C., in charge of field engineering service on projects sponsored by the Rural Electrification Administration. He returned to the Anaconda company for a time in 1940 and more recently has been in private consulting practice on rural electrification.

W. A. Perry (M'38) superintendent, electrical and power departments, Inland Steel Company, East Chicago, Ind., has been elected president of the Association of Iron and Steel Engineers for the coming year. A native (1894) of New York, he went to the Inland Steel Company as an apprentice in 1910, becoming mill motor foreman in 1919. He became assistant superintendent of the power department in 1925, assistant superintendent of the electrical department in 1927, and has been superintendent of the two departments since 1931.

R. R. Pittman (A'28) formerly electrical engineer, Arkansas Power and Light Company, Pine Bluff, has been appointed chief engineer. Born June 27, 1894, at Ottumwa, Iowa, he received the degree of bachelor of science in electrical engineering from Iowa State College in 1917. During the World War he was an instructor for the United States Army Signal Corps at the University of Oklahoma. Since 1918 he has been with the Arkansas Power and Light Company, first as distribution engineer and since 1925 as electrical engineer.

E. T. B. Gross (A'34, M'40) former head of the engineering division, central-station department, A.E.G.-Union Electric and Manufacturing Company, Vienna, has been appointed Westinghouse research associate at Cornell University, Ithaca, N. Y. He received the degrees of electrical engineer, 1923, and doctor of science, 1932, from the Vienna Institute of Technology. He was associated with A.E.C.-Union from 1924 to 1938. For the past year he has been a visiting doctor at Cornell and engaged in consulting practice at Ithaca.

F. W. Rullson (M'32) has retired as chief engineer of the Iowa area of the Northwestern Bell Telephone Company, Des Moines. He was born March 12, 1884, near Topeka, Kans., and entered the employ of the Iowa Telephone Company, predecessor of Northwestern Bell, in 1902. In 1911 he became plant engineer for the Iowa company and in 1919 plant superintendent. He was made outside plant engineer for Northwestern Bell Telephone Company in 1925 and has been chief engineer of the Iowa area since 1928.

A. R. Rutter (A'35) formerly section engineer, watt-hour meters, meter division, Westinghouse Electric and Manufacturing Company, Newark, N. J., has been appointed assistant manager of the engineering department of the meter division. He entered the employ of the company at East Pittsburgh in 1918, and has been section engineer since the transfer of the meter division to Newark in 1928.

C. C. MacAllister (A'37) formerly in charge of traffic control and signal equipment sales, General Electric Company, Schenectady, N. Y., has been transferred to the River Works of the company, Lynn, Mass., where he will be engaged in the design of such equipment. He has been with the company since 1936.

T. J. Martin (A'35) formerly electrical engineer, Commonwealth Edison Company, Chicago, Ill., is now with Lockheed Aircraft

Corporation, Burbank, Calif., taking the special training course for engineers being given by that organization in co-operation with California Institute of Technology.

A. S. Albright (M'37) superintendent of meters, Detroit Edison Company, Detroit, Mich., has been appointed acting chief of research, during the absence of Douglas Dow, chief of research, on advisory service to the United States Army.

M. C. Titus (A'39) formerly transit man and acting electrical inspector, Roza project, United States Bureau of Reclamation, Yakima, Wash., is now employed as an assistant engineer by the Bonneville Power Administration, Portland, Ore.

B. F. Thomas, Jr. (A'14, M'29) formerly principal engineer for the Public Works Administration, Washington, D. C., is now employed as electrical and mechanical engineer by the Foundation Company, New York, N. Y.

P. D. Rossiter (A'33) formerly mill electrician for the Britannia Mining and Smelting Company, Ltd., Britannia Beach, B. C., Canada, is now employed as electrical draftsman by the Alberta Nitrogen Company, Calgary, Alberta, Canada.

M. W. Leslie (A'39) formerly teaching assistant at the University of Minnesota, Minneapolis, is now a member of the electrical engineering department, College of Engineering, Wayne University, Detroit, Mich.

K. T. Compton (F'31) president, Massachusetts Institute of Technology, Cambridge, has been awarded the honorary degree of doctor of science by Columbia University.

R. K. Lane (M'37) president, Public Service Company of Oklahoma, and Southwestern Light and Power Company, Tulsa, has been elected president of the Oklahoma Utilities Association.

O. H. Klippel (A'36) formerly electrical draftsman for the United Light and Power Service Company, Kansas City, Mo., is now employed by the Solvay Process Company, Hopewell, Va.

P. O. Weston (A'35) formerly manager of the St. Louis, Mo., office of the Rockbestos Products Corporation, is now Pacific Coast manager with headquarters at San Francisco, Calif.

J. S. Lieb (A'35) formerly representative of Allis-Chalmers Manufacturing Company at New York, N. Y., has been transferred by the company to the patent department at Milwaukee, Wis.

J. G. Barry (A'38) formerly research assistant, Bartol Research Foundation, Franklin Institute, Philadelphia, Pa., is now an instructor in electrical engineering at Princeton University, Princeton, N. J.

John Happy (A'40) formerly employed in the engineering department of the Ohio Public Service Company, Port Clinton, is now with the Swartwout Company, Cleveland, Ohio.

Everett Eberhard (A'39) formerly instructor in electrical engineering, South Dakota State College, Brookings, is now employed in the engineering department of Hobart Brothers Company, Troy, Ohio.

C. F. Myers (A'31) formerly assistant superintendent, central division, Puget Sound Light and Power Company, Seattle, Wash., has been promoted to general engineering, with broader duties.

F. H. Travers (A'26, M'32) is now with the electrical engineering division of the Philadelphia Electric Company, Philadelphia, Pa.

W. M. Allen (A'27) commercial representative, Pacific Telephone and Telegraph Company, has been transferred from Spokane, Wash., to Seattle, Wash.

M. W. Brown (A'34) formerly power dispatcher, P. R. Mallory and Company, Indianapolis, Ind., is now employed by Fairbanks Morse Company, Beloit, Wis.

H. W. Giesecke (A'35) formerly with the Research Corporation, Bound Brook, N. J., is now employed by Celanese Corporation of America, Narrows, Va.

H. V. Scarborough, Jr. (A'38) formerly test man with General Electric Company, is now employed by the Carolina Power and Light Company, Asheville, N. C.

H. L. Miller (A'38) president, Utilities Engineering Company, Philadelphia, Pa., has been elected vice-president of the Electrical Association of Philadelphia for 1941.

F. A. Graham (M'30) former superintendent, power sales, Kansas City Power and Light Company, Kansas City, Mo., has been made manager of power sales.

A. E. Harrison (A'39) is now employed by the Sperry Gyroscope Company, Garden City, N. Y.

Obituary • • •

Charles Augustus Stone (A'91, M'07) cofounder and chairman of the board, Stone and Webster, Inc., New York, N. Y., died February 25, 1941. He was born at Newton, Mass., January 16, 1867, and was graduated from the electrical-engineering course at Massachusetts Institute of Technology in 1888, with the degree of bachelor of science, receiving the honorary degree of master of science from Harvard University in 1914. After working in the research laboratory of the Thomson Electric Welding Company and for the C. and C. Motor Company, he formed a partnership with Edwin S. Webster in 1889, originally under the name of Massachusetts Electrical Engineering Company, Stone and Webster, managers. The firm designed and supervised operation of electric light and power plants and street railways, and later began to assume management of electrical utilities for private owners, subsequently taking over also the management of gas plants, water-supply systems, central steam heating plants, and bus companies. In the early 1900s the firm also undertook the financing of utility companies, and thus entered the investment banking field, where its functions were later taken over by Stone and Webster and Blodget, Inc., of which Mr. Stone was a director. During the World War the organization built the 50-way shipyard at Hog Island, Pa., which served as an assembling plant for shipbuilding, and also built the cantonment at Kelley Field, Tex., and the ordnance base for the American Expeditionary Force in France, as well as other war construction. Mr. Stone was instrumental in the organization in 1925 of the Engineers Public Service Company, for some time a subsidiary of Stone and Webster, Inc., and was its chairman for some years. He was a director of the Federal Reserve Bank of New York, 1919–23, director of various other companies, and member of several technical societies.

William Horatio Freedman (A'90, M'95, F'13) retired electrical consultant, Nyack, N. Y., died recently, according to information just received. He was born at New York, N. Y., December 28, 1867, and after studying at the College of the City of New York, received the degrees of civil engineer, 1889, and electrical engineer, 1891, at Columbia University, and later that of master of science from the University of Vermont. He continued at Columbia as graduate student, tutor, and from 1893 to 1899 as instructor in electrical engineering. During the period 1894–99 he was a member of the firm of Freedman, Rennard, and Company, electrical engineers and contractors. He became professor of electrical engineering at the University of Vermont, Burlington, in 1899, and except for the years 1910–13, when he was head of the department of applied electricity at Pratt Institute, Brooklyn, N. Y., continued at Vermont until 1920. He also carried on consulting practice. Later he was technical employment representative for the American Telephone and Telegraph Company, New York, N. Y., and research engineer for the Bonded Products Corporation, New York, and from 1925 until his retirement several years ago practiced as an electrical consultant and technical writer at Nyack, N. Y. He was also a member of the American Association for the Advancement of Science, the Society for the Promotion of Engineering Education, and the Institute of Radio Engineers.

Jack B. Hill (A'10, M'13) vice-president, American Gas and Electric Service Corporation, New York, N. Y., died January 19, 1941, at Orange, N. J. He was born January 20, 1881, at Jonesboro, Ind., and received the degrees of bachelor of science in electrical engineering, 1905, and electrical engineer, 1922, from Purdue University. He interrupted his college career to enter the apprentice course of Westinghouse Electric and Manufacturing Company at Pittsburgh, Pa., and from 1902 to 1904 was assistant electrical engineer for the Oliver Iron and Mining Company, Eveleth, Minn. After graduation, he spent three years with Union Electric Light and Power Company, St. Louis, Mo., as draftsman and later superintendent of electrical construction on substations. He then returned to Westinghouse for a time as salesman at the Memphis, Tenn., office. In 1909 he became instructor in electrical engineering, University of Iowa, Iowa City, and later assistant professor, remaining on the faculty for 14

years. In 1923 he became vice-president and general manager, Lincoln (Nebr.) Gas and Electric Company, later holding the same position with the Ohio Utilities Company, Columbus, until 1928, when he became assistant to the vice-president in charge of operations, American Gas and Electric Company, New York. He became a vice-president of that company about 1935, and of American Gas and Electric Service Corporation about two years later.

Thomas Witt Fitzgerald (A'15, M'21) head of the department of electrical engineering, Georgia School of Technology, Atlanta, died February 20, 1941. He was born November 16, 1885, at Wolf Creek, W. Va., completed the academic course at Marshall College in 1905, and received the degrees of bachelor of science in mechanical engineering, 1909, and electrical engineer, 1924, from the University of West Virginia, and that of master of science, 1925, from Emory University. He was a student engineer with the Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa., 1909–10, and from 1910 to 1912 was employed in the electrical maintenance department of the New River and Pocahontas Consolidated Coal Company. He became an instructor in electrical and mechanical engineering, Michigan Agricultural College, Lansing, in 1912, and in 1914 went to the University of Arizona, where he was assistant professor in charge of the electrical engineering department until 1918. From 1918 to 1920 he was electrical engineer in charge of maintenance and construction for the Ray Consolidated Copper Company, Hayden, Ariz. He had been professor of electrical engineering and head of the department at Georgia School of Technology since 1920. He was also a member of Tau Beta Pi and the Society for Promotion of Engineering Education.

Henry Lumsden Woolfenden (A'17, M'17) retired head of the mechanical-engineering department, Lawrence Institute of Technology, and consulting engineer, Detroit, Mich., died January 19, 1941. He was born July 15, 1874, at Detroit, and received the degrees of bachelor of science in electrical engineering, 1896, master of science, 1897, and electrical engineer, 1904, from the University of Michigan. In 1897 he was employed by Gilbert Wilkes, consulting engineer, Detroit, and in 1899 became a partner. He became treasurer of the firm in 1900 on its incorporation, and in 1901 became president, taking charge of the Denver, Colo., office. In 1905 he was employed by Allis-Chalmers Manufacturing Company as salesman in charge of the power department of the Denver office, and in 1910 became district manager. He continued consulting work during this period. In 1918 he formed the consulting firm of Woolfenden, Wood, and Weber, Denver, practicing there until 1922, when he returned to Detroit to head the Elliot-Taylor-Woolfenden Company, department store. He returned to sales engineering in 1925 and continued until his retirement in January 1940. During this period he also headed the department of mechanical engineering of Lawrence Institute of Technology.

Lawrence J. Montgomery (A'18) manager, special business bureau, sales department, Consolidated Edison Company of New York, Inc., New York, N. Y., died January 21, 1941, at West Palm Beach, Fla. He was born at Susquehanna, Pa., May 30, 1884, and graduated in electrical engineering from Pratt Institute. He was employed in the test department of General Electric Company, Schenectady, N. Y., in the testing laboratories of the New York Edison Company, and by Cowden and De Young, electrical contractors, before entering the power sales department of the New York and Queens Electric Light and Power Company about 1911. He became power agent in 1912, assistant general sales manager in 1917, and general sales manager in 1934. He was transferred to Consolidated Edison in 1937 as manager of the sales technical bureau, and became manager of the special business bureau in 1940.

Wallace Theodore Gill (A'31) vice-president and general manager, Piedmont and Northern Railway, Charlotte, N. C., died January 28, 1941, at Greenville, N. C. He was born at Richland, Fla., September 26, 1886, and attended the University of Florida. He had been in railroad work since 1901, when he was employed as switch tender by the Atlantic Coast Line. He was with the Charlotte Harbor and Northern Railway 1907–08; with the Florida East Coast Railway, 1908–09. In 1909 he became chief clerk and traveling auditor for the Carolina and Northwestern Railway. He had been with the Piedmont and Northern Railway since 1912, becoming assistant to the general manager in charge of operation and maintenance in 1925. He became general manager in 1934, and vice-president in 1935, and also had held those positions with the Durham and Southern Railway since 1935.

Andrew Kenneth Selden, Jr. (A'03) engineering department, Crocker-Wheeler Electric Manufacturing Company, Ampere, N. J., died October 3, 1940, according to information just received. He was born in Jefferson County, W. Va., November 26, 1880, and received the degree of bachelor of science in electrical engineering at the University of Tennessee in 1900. Following graduation he entered the test department of General Electric Company at Lynn, Mass., and in 1902 was transferred to the d-c motor engineering department as assistant engineer. He was later employed by the Electro-Dynamic Company, Bayonne, N. J., for several years. He had been with the Crocker-Wheeler Company since 1912.

Reuben Irving Wright (A'04, M'07, F'13) retired director and chief engineer of the Electric Controller and Manufacturing Company, Cleveland, Ohio, died January 4, 1941. He was born April 10, 1876, at Sedalia, Mo., and received his technical education at the Lawrence Scientific School of Harvard University. He worked as electrical draftsman for the Brown Hoisting Machinery Company, Cleveland, and the Wellman-Seaver-Morgan Company, before joining the Electric Controller and Supply Company in 1900. He was successively draftsman, chief draftsman, assistant engineer, sales engineer, engineer, and eventually chief engineer and a director of the company. He retired in 1920.

Masajiro Yonezawa (A'25) lecturer, Tokyo Technical University, Tokyo, Japan, died February 9, 1940, according to information just received. He was born at Tottori City, Japan, February 14, 1882, and was graduated in 1907 from the college of electrical engineering of the Tokyo Imperial University. He became an electrical engineer for the Japanese Government Railways in 1909 and continued in that capacity until 1932, spending some time in the United States as resident representative, with headquarters in New York, N. Y. He had held his position with the Tokyo Technical University since 1932.

Carl Henry Hoge (A'19, M'29) assistant engineer, Puget Sound Power and Light Company, Seattle, Wash., died January 12, 1941. He was born March 9, 1886, at Wenona, Ill., and received the degree of bachelor of science from the University of Illinois in 1909. He was employed by the Seattle (Wash.) Electric Company and by the Pacific Telephone and Telegraph Company before becoming a distribution engineer for the Puget Sound company in 1914. In 1924 he became construction superintendent, distribution department, and later assistant engineer.

Membership • •

Recommended for Transfer

The board of examiners, at its meeting on March 13, 1941, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Boyce, B. K., vice-president and general manager, New York Telephone Company, New York.
Clarke, H. O., Jr., executive vice-president, assistant general manager, and director, Houston Lighting and Power Company, Houston, Tex.
Hughes, R. H., vice-president and general manager, New York Telephone Company, New York.
Plumb, H. T., consulting engineer, General Electric Company, Salt Lake City, Utah.
Taylor, A. L., dean, school of mines and engineering, University of Utah, Salt Lake City, Utah.
Ward, O. M., superintendent of electrical operation, Wisconsin Electric Power Company, Milwaukee, Wis.

6 to Grade of Fellow

To Grade of Member

Cahill, F. B., designing engineer, General Electric Company, Pittsfield, Mass.
Casey, H. J., assistant safety engineer, Baltimore Transit Company, Baltimore, Md.
Chambers, D. E., assistant engineer, General Electric Company, Schenectady, N. Y.
Cobine, J. D., faculty instructor, Harvard University, Cambridge, Mass.
Jones, H. E., equipment and building engineer, Mountain States Telephone and Telegraph Company, Denver, Colo.
Pearson, H. R., engineer, Dallas Power and Light Company, Dallas, Texas.
Poti, W. M., assistant engineer, New York and Queens Electric Light and Power Company, Flushing, N. Y.
Sanderson, W. D., foreman engineer, Detroit Edison Company, Detroit, Mich.

8 to Grade of Member

Applications for Election

Applications have been recieved at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by

geographical Districts. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before April 30, 1941 or June 30, 1941 if the applicant resides outside of the United States or Canada.

United States and Canada

1. NORTH EASTERN

Adams, C. G., General Electric Company, Schenectady, N. Y.
Adams, G. M., General Electric Company, Schenectady, N. Y.
Atkinson, W. R., Northborough High School, Northboro, Mass.
Bardwell, M. W. (Member), Central New York Power Corporation, Syracuse, N. Y.
Barry, L. B., General Electric Company, Schenectady, N. Y.
Bean, W. S., Jr., General Electric Company, Schenectady, N. Y.
Becker, J. A., Jr., General Electric Company, Pittsfield, Mass.
Bendz, W. I. (Member), Westinghouse Electric and Manufacturing Company, Boston, Mass.
Bigbie, D. D., United States Army, 187th Field Artillery, Fort Ethan Allen, Vt.
Black, E. N., General Electric Company, Schenectady, N. Y.
Borkowksi, C. J., Colonial Radio Corporation, Buffalo, N. Y.
Brudzynski, A. J., General Electric Company, Lynn, Mass.
Burton, L. A., General Electric Company, Schenectady, N. Y.
Carriere, C. A., General Electric Company, Schenectady, N. Y.
Chamberlin, J. R., Jr., General Electric Company, Schenectady, N. Y.
Chestnut, H., General Electric Company, Schenectady, N. Y.
Codichini, J. J., Scintilla Magneto Company, Sidney, N. Y.
Comstock, A. N., Connecticut Light and Power Company, Norwalk, Conn.
Crowell, C. D., General Electric Company, Syracuse, N. Y.
Dana, G. E., New York State Electric and Gas Corporation, Binghamton, N. Y.
Delany, F. J., United States Navy Department, General Electric Company, Bridgeport, Conn.
DeVore, T. D., Central New York Power Corporation, Oswego, N. Y.
Dice, J. W., Westinghouse Electric and Manufacturing Company, Syracuse, N. Y.
Faulkner, R. E., Central New York Power Corporation, Potsdam, N. Y.
Freer, G. B., Jr. (Member), Central New York Power Corporation, Syracuse, N. Y.
Gagne, W. N., United States Electrical Motors, Incorporated, Milford, Conn.
Gethmann, R. B., General Electric Company, Bridgeport, Conn.
Hardy, B. B., Aerovox Corporation, New Bedford, Mass.
Higgs, R. E., Factory Insurance Association, Hartford, Conn.
Holmes, L. L., Jr., General Electric Company, Schenectady, N. Y.
Howard, C., Jr., General Electric Company, Schenectady, N. Y.
Hutchinson, R. L., Harvard University Graduate School of Engineering, Cambridge, Mass.
Jarvis, T. F., Warsaw Electric Company, Warsaw, N. Y.
Kellogg, H. L., General Electric Company, Schenectady, N. Y.
Kessler, M. E., International Business Machines Corporation, Endicott, N. Y.
Kilcoin, J. A., Jr., Stone and Webster Engineering Corporation, Boston, Mass.
Kurtz, R. B., General Electric Company, Schenectady, N. Y. (for mail: 37 Washington Place, Ridgewood, N. J.).
Lebenbaum, M. T., Massachusetts Institute of Technology, Cambridge, Mass.
Larstrup, K. (Member), Tufts College, Medford, Mass.
Levin, K. L., Colonial Radio Corporation, Buffalo, N. Y.
Lewis, D. C., Central New York Power Corporation, Utica, N. Y.
Livingood, H. L., New York State Electric and Gas Corporation, Binghamton, N. Y.
Lloyd, H. R., Jr., General Electric Company, Schenectady, N. Y. (for mail: 1839 Holly Street, Harrisburg, Penna.).
Lynn, W. B., General Electric Company, Schenectady, N. Y.
Mandil, I. H., Massachusetts Institute of Technology Graduate House, Cambridge, Mass.
McMillan, M. V., Buffalo Niagara Electric Corporation, Buffalo, N. Y.
Meranda, J. I., Bethlehem Steel Company, Lackawanna, N. Y.
Meyers, P. A., General Electric Company, Pittsfield, Mass.
Miller, J. F., General Electric Company, Lynn, Mass.
Niebuhr, W. F., Jr., General Electric Company, Schenectady, N. Y.
Nitz, H. L., General Electric Company, Schenectady, N. Y.
Nolan, W. J., Jr., Rensselaer Polytechnic Institute, Troy, N. Y.
Oliver, C. H., Central New York Power Corporation, Utica, N. Y.
Page, J. C., General Electric Company, Schenectady, N. Y.
Papenhausen, R. W., General Electric Company, Schenectady, N. Y.
Pearson, T. J., Jr., Boston Edison Company, Boston, Mass. (for mail; 71 Nesmith Street, Lawrence, Mass.).
Person, K. S., Norton Company, Worcester, Mass.
Personius, K. E. (Member), New York State Electric and Gas Corporation, Elmira, N. Y.
Reuter, J. E., General Electric Company, Pittsfield, Mass.
Roberts, D., General Electric Company, Schenectady, N. Y. (for mail: 43 Fern Street, New Rochelle, N. Y.).
Russ, R. B., General Electric Company, Schenectady, N. Y.
Schlawin, R. G., General Electric Company, Schenectady, N. Y.
Schneider, P. J., Central New York Power Corporation, Fulton, N. Y.
Schnure, R. B., General Electric Company, Schenectady, N. Y.
Schwarz, S. J., Stone and Webster Engineering Corporation, Boston, Mass.
Scott, S. E., United States Army, Camp Edwards, Mass.
Sheridan, B. W., Massachusetts Institute of Technology, Cambridge, Mass.
Sills, R. M., Jr., General Electric Company, Schenectady, N. Y.
Skeirik, R. M., International Business Machines Corporation, Endicott, N. Y.
Sorace, K. J., Rochester Gas and Electric Corporation, Rochester, N. Y.
Steele, R. B., General Electric Company, Schenectady, N. Y.
Stevens, T. H., Central New York Power Corporation, Watertown, N. Y.
Strong, W. F., General Electric Company, Schenectady, N. Y.
Swartwout, D. K., 3rd, General Electric Company, Pittsfield, Mass.
Taylor, C. M. (Member), Central New York Power Corporation, Syracuse, N. Y.
Taylor, G. A., Central New York Power Corporation, Syracuse, N. Y.
Upham, S. W., General Electric Company, Schenectady, N. Y.
Vincent, H. F., International Business Machines Corporation, Endicott, N. Y.
von Sothen, C. B. H. (Member), General Electric Company, Syracuse, N. Y.
Wartinbee, W. J., General Electric Company, Pittsfield, Mass.
Weeks, R., Jr., Electrolux Corporation, Old Greenwich, Conn.
Were, A. R., General Electric Company, Schenectady, N. Y.
Wieser, C. R., Boston Edison Company, Boston, Mass.
Willis, E. W., 341 Warren Street, Needham, Mass.
Wright, R. D., General Electric Company, Lynn, Mass.
Wyrick, L. L., General Electric Company, Pittsfield, Mass.
Zingrebe, O. C., General Electric Company, E. Lynn, Mass.

2. MIDDLE EASTERN

Ainsworth, J. L., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Penna.
Akers, H. T., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Allen, D. E., Rural Electrification Administration, Washington, D. C.
Anderson, L. L., Hygrade Sylvania Corporation, Emporium, Penna.
Andreas, J. C., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.
Arndt, M. H., Westinghouse Electric and Manufacturing Company, Washington, D. C.
Arnett, L. C., Howard University, Washington, D. C.
Askegaard, D. H., Rural Electrification Administration, Washington, D. C.
Astin, J. S., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Penna.
Atkinson, G. D., Jr., Federal Power Commission, Washington, D. C.
Auten, L. D. (Member), Fredericktown, Ohio.
Balog, M., Glenn L. Martin Company, Baltimore, Md. (for mail Box 115, Vintondale, Pa.).
Barborowski, J., Pennsylvania Electric Company, Johnstown, Pa.
Barnes, E. C., Reliance Electric and Engineering Company, Cleveland, O.
Bauman, A., Rural Electrification Administration, Washington, D. C. (for mail Warrensburg, Ill.).
Bernhart, C. B., Jr., Carnegie-Illinois Steel Corporation, Vandergrift, Penna.
Bichsel, H. J., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.
Birmingham, W. T., Central Police Station, Traffic Engineering Division, Cleveland, Ohio.
Bobula, J., Westinghouse Electric and Manufacturing Company, Forest Hills, Penna.
Brooks, J. D., U. S. Housing Authority, Washington, D. C.
Buck, D. H., General Electric Company, Washington, D. C.
Bunk, J. S., Erie Lighting Company, Erie, Pa.
Burmeister, F. H., Air-Way Electrical Appliance Corporation, Toledo, O.
Calvarese, J. F., RCA Manufacturing Company, Incorporated, Camden, N. J.
Caplan, N., RCA Manufacturing Company, Camden, N. J.
Carter, R. C., United States Coast Guard, Cleveland, Ohio.
Close, R. H., Roller Smith Company, Bethlehem, Pa.
Coleman, R. E., Jr., General Electric Company, Philadelphia, Pa.
Comstock, J. A., Acme Electric and Manufacturing Company, Cleveland, Ohio.
Cooper, H., Campbell Soup Company, Camden, N. J.
Cunningham, J. H., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Deucher, T. F., Ohio Electric Manufacturing Company, Cleveland, Ohio.
Duckwald, C. S., Jr., Ideal Electric and Manufacturing Company, Mansfield, Ohio.
Faulk, D. P., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Feher, L. H. G., Lehigh Structural Steel Company, Allentown, Penna.
Fielder, D. C., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Fields, R. E., Rural Electrification Administration, Washington, D. C.
Fiet, O. O., RCA Manufacturing Company, Incorporated, Camden, N. J.
Freeman, B., Pennsylvania Railroad Company, Pittsburgh, Pa.
Garrett, P. T., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.
Gill, E. G., Jr., Gill and Simpson Electrical Company, Baltimore, Md.
Gilman, S., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.
Godard, R. R., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.
Griswold, A. W., Clark Controller Company, Cleveland, Ohio.
Gulnac, H. D., Bell Telephone Company of Pennsylvania, Philadelphia, Pa. (for mail: 323 Allenhurst Avenue, Ridgway, Penna.).
Gutheim, R. J., Potomac Electric Power Company, Washington, D. C.
Hammell, A. E., Jr., Monitor Controller Company, Baltimore, Md.
Harbage, B., Jeffrey Manufacturing Company, Columbus, Ohio.
Harris, M., 815 Edgewood Avenue, Charleston, W. Va.
Harvey, J. A., Jr., Pennsylvania Electric Company, Johnstown, Pa.
Heckel, R. D., Navy Department, Philadelphia, Penna.
Heinze, L. O., Delco Products Corporation, Dayton, O.
Hower, J. F., American Steel and Wire Company, Cleveland, O.
Hymowitz, H. M., Navy Department, Philadelphia, Penna.
Ide, H. A., Rural Electrification Administration, Washington, D. C.
Ivy, J. G., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.
James, R. C., Public Service Electric and Gas Company, Burlington, N. J.
Jenkins, W. L., B. F. Goodrich Company, Akron, Ohio.
Karlsson, C. B. E., E. I. du Pont de Nemours and Company, Incorporated, Wilmington, Del.
Kehl, H. A., Lincoln Electric Company, Cleveland, Ohio.
Keiffer, R. L., General Electric Company, Erie, Pa.
Keirn, G. F., Goodyear Tire and Rubber Company, Akron, Ohio.
Keller, W. B., Cleveland Electric Illuminating Company, Cleveland, Ohio.
Kelley, W. E., Pennsylvania Railroad, Altoona, Pa.
Kennedy, M., Westinghouse Electric and Manufacturing Company, Washington, D. C.
Kerstetter, D. R., Hygrade Sylvania Corporation, Emporium, Penna.
Kirkland, C. W., Jr., Ohio Power Company, Bellaire, Ohio.
Kirwan, J. G., University or Pittsburgh, Pittsburgh, Penna.
Koehler, G. A., Procter and Gamble Company, Ivorydale, Ohio.
Koenig, F. E., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.
Leon, R. E., Rural Electrification Administration, Washington, D. C.
Levy, T. A., General Electric Company, Philadelphia, Pa.
Linder, F. W., Rural Electrification Administration, Washington, D. C.
Lowy, W. M., Bethlehem Steel Company, Sparrows Point, Md.
Lynch, E., Jr., Pennsylvania Railroad Company, Altoona, Penna.
Manner, C. J., Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.
Marsh, O. H., General Electric Company, Philadelphia, Pa.
Mason, W. S., Albright and Friel Incorporated, Aberdeen, Maryland.
Meeds, L. T., Chesapeake and Potomac Telephone Company, Washington, D. C.
Menapace, R. H., Glenn L. Martin Company, Baltimore, Md.
Menten, R. A., Allegheny Ludlum Steel Corporation, Brackenridge, Penna.
Metz, T. W., Allis-Chalmers Manufacturing Company, Philadelphia, Pa.
Miller, G. M., Bethlehem Steel Company, Bethlehem, Penna.
Morgan, D. R., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.

Moulton, J. F. (Member), Chesapeake and Potomac Telephone Company, Washington, D. C.
Murrie, J. L. (Member), Federal Power Commission, Washington, D. C.
Muszynski, E. L., Philadelphia Company, Pittsburgh, Pa.
Myers, C. S., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.
Nelson, V. J., Ohio Power Company, Newark, Ohio.
Nims, A. A., Jr., Westinghouse Electric and Manufacturing Company, Baltimore, Md.
Opel, L. G., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.
Ostrander, W. M., Westinghouse Electric and Manufacturing Company, Cleveland, O.
Panian, R. M., Frigidaire Corporation, Dayton, Ohio.
Payne, S., Lincoln Electric Company, Cleveland, Ohio.
Percy, R. P., Westinghouse Electric and Manufacturing Company, Lima, Ohio (for mail: 648 South 17th Street, Lincoln, Nebraska).
Pettersen, R. A., Pennsylvania Railroad, Altoona, Pa. (for mail: 7 East 17th Street, Brooklyn, N. Y.).
Plotkin, I., Bureau of Ships, Navy Department, Washington, D. C.
Posener, A. W., Jr., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.
Proctor, V., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.
Ramsay, J. D., Campbell Soup Company, Camden, N. J.
Raney, J. J., Yale and Towne Manufacturing Company, Philadelphia, Pa.
Reid, G. E., National Tube Company, Ellwood City, Pa.
Reilly, J. E., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Reynolds, F. E., General Electric Company, Philadelphia, Pa.
Rich, E. S., Brush Development Company, Cleveland, Ohio.
Ristzke, E. H. (Member), Capitol Radio Engineering Institute, Washington, D. C.
Rogers, C. J., Rural Electrification Administration, Washington, D. C.
Rogge, R. S., Duquesne Light Company, Pittsburgh, Pa.
Rolfsen, G. J., Western Union Telegraph Company, Cincinnati, Ohio.
Sane, J. H., Republic Steel Corporation, Cleveland, Ohio.
Savage, J. W., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Schimke, C. F., Monongahela West Penn Public Service Company, Fairmont, West Va.
Sebastian, G. C., Philadelphia Electric Company, Philadelphia, Pa.
Shaffer, W. L., The Brown Instrument Company, Philadelphia, Pa.
Shaw, B. W., Potomac Electric Power Company, Washington, D. C.
Shelly, W. M., Pennsylvania Power and Light Company, Hazleton, Pa.
Spencer, D. C., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Penna.
Swickard, B. O., Jr., Calvert Distilling Company, Relay, Md.
Terrant, F. R., Reliance Electric and Engineering Company, Cleveland, O.
Theroux, L. N., War Department, Aircraft Radio Laboratory, Dayton, O.
Thomas, L. A. (Member), Rural Electrification Administration, Washington, D. C.
Towle, E. H., United States Navy, Bureau of Ordnance, Washington, D. C. (for mail: 79 Grant Avenue, Albany, N. Y.)
Unverzagt, E. A., Rex-Chalmers Manufacturing Company, Pittsburgh, Penna.
VanHouten, E. H., United States Army, Fort Dix, N. J.
Verkley, B. M., American Rolling Mills Company, Middletown, Ohio.
Warren, C. B., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Penna.
West, O. W., United States Government, Maritime Commission, Washington, D. C.
Williams, H. S., Rural Electrification Administration, Washington, D. C.
Willis, A. H., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.
Wilson, T. L., RCA Manufacturing Company, Incorporated, Camden, N. J.
Winemiller, M. F., Aeronautics, Navy Department, Philadelphia, Pa.
Woestemeyer, F. B., General Electric Company, Philadelphia, Pa.
Woodall, R. C., Bethlehem Steel Company, Steelton, Pa.
Yetter, J. W., General Electric Company, Philadelphia, Pa.
Zalak, R. R., General Electric Company, Cleveland, Ohio.

3. New York City

Abolin, C. H., Jr., Kenyon Transformer Company, New York, N. Y.
Allen, J. W. (Member), Bendix Aviation Corporation, Bendix, N. J.
Babitt, B. B., Babitt Electric Company, Incorporated, New York, N. Y.
Bailey, M., Sperry Gyroscope Company, Brooklyn, N. Y.
Bayle, A., War Department, United States Government, Brooklyn, N. Y.
Beckman, C., Westinghouse Electric and Manufacturing Company, Bloomfield, N. J.
Benedetti, J., Harry Alexander, Incorporated, New York, N. Y.
Biews, R. R., Jr., Curtiss-Wright Corporation, Caldwell, N. J.
Bowker, M. W., Bell Telephone Laboratories, Incorporated, New York, N. Y.
Brenneman, D. E., Bell Telephone Laboratories, Incorporated, New York, N. Y.
Buonincontri, J., Westinghouse Electric and Manufacturing Company, Newark, N. J.
Burns, T. (Member), American Gas and Electric Service Corporation, New York, N. Y.
Cassidy, B. F. R., Signal Corps Laboratories, Fort Monmouth, Red Bank, N. J.
Crosby, P. F., Public Service Electric and Gas Company, Newark, N. J.
Dyktor, G. J., Long Island Lighting Company, Roslyn Heights, N. Y.
Dziuma, E., Bendix Aviation Corporation, Brooklyn, N. Y.
Eisler, C., Jr., Eisler Engineering Company, Newark, N. J.
Falconetti, S. L., United States Navy, Wright Aeronautical Corporation, Paterson, N. J.
FitzSimmons, L. G., Jr., Bell Telephone Laboratories, Incorporated, New York, N. Y.
Frankel, D. S., Western Electric Company, Kearny, N. J.
Frazier, W. B., Cambridge Instrument Company, Ossining, N. Y.
Graham, W. F., Consolidated Edison Company of New York, Incorporated, New York, N. Y.
Grob, M. P., United States Navy, New York, N. Y.
Grode, J. D., Brooklyn Navy Yard, Brooklyn, N. Y.
Gunzbourg, P. M. (Member), 330 East 56th Street, New York, N. Y.
Hinrichs, J. H., Navy Yard, Brooklyn, N. Y.
Johansson, G., Western Electric Company, Kearny, N. J.
Joseph, J. L., United States Army, Signal Corps, Fort Monmouth, N. J.
Kotrbaty, J. (Member), E. J. Cheney and Company, New York, N. Y. (for mail: 117 Robbins Avenue, Rockledge, Philadelphia, Pa.).
Kraut, C. F., Ward Leonard Electric Company, Mt. Vernon, N. Y.
Kristensen, M. H., Elastic Stop Nut Corporation, Union, N. J.
McGivney, F. A., M. W. Kellogg Company, New York, N. Y.
Moran, J. M., American Cyanamid Company, Plainfield, N. J.
Moskowitz, S., Industrial Scientific Corporation, New York, N. Y.
Moyer, R. M., Wright Aeronautical Corporation, Paterson, N. J.
Mueller, H., The Liquidometer Corporation, Long Island City, N. Y.
Nye, J. H., Western Union Telegraph Company, New York, N. Y.
Papst, H. W. (Member), Anaconda Wire and Cable Company, Hastings-on-Hudson, N. Y.
Payne, T. A. (Member), New York and Queens Electric Light and Power Company, Astoria, N. Y.
Pegnim, T. C., Sperry Products Incorporated, Hoboken, N. J.
Pettit, J. A., Jr., War Department, Signal Corps, Brooklyn, N. Y.
Plotkin, O., War Department, New York Signal Corps Procurement District, Brooklyn, N. Y.
Pockmerski, D., United States Navy Department, New York, N. Y.
Port, J., War Department, New York Signal Corps, Procurement District, Brooklyn, N. Y.
Post, A. W., Long Island Lighting Company, Roslyn Heights, L. I., N. Y.
Potts, R. M., Parkchester Housing, New York, N. Y.
Pruden, J. H., Westinghouse Electric and Manufacturing Company, Newark, N. J.
Prysie, J. B. (Member), New York and Queens Electric Light and Power Company, Astoria, L. I., N. Y.
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Rudensey, M. B., Federal Telegraph Company, Newark, N. J.
Ruth, J. A., International Business Machines Corporation, New York, N. Y.
Salkind, H., War Department, New York Signal Corps, Procurement District, Brooklyn, N. Y.
Salvadore, A. M., Central Hudson Gas and Electric Corporation, Poughkeepsie, N. Y.
Savage, N., United States Navy Yard, New York, N. Y.
Schmidt, H. P., Westinghouse Electric and Manufacturing Company, Newark, N. J.
Schreiner, L. R., Bell Telephone Laboratories, Incorporated, New York, N. Y.
Shank, H. M., Consolidated Edison Company of New York, Incorporated, New York, N. Y.
Shaw, L. R., Underwriters' Laboratories, Incorporated, New York, N. Y.
Smith, A., Westinghouse Electric International Company, New York, N. Y.
Soman, R. O., Diehl Manufacturing Company, Elizabethport, N. J.
Tanner, E. C., New York Thread Grinding Corporation, New York, N. Y.
Trench, R. B., New York Telephone Company, New York, N. Y.
Van Zee, W. H., Ocean Accident and Guarantee Corporation, Limited, New York, N. Y.
Walker, A. C., War Department, New York Signal Corps Procurement District, Brooklyn, N. Y.
Warne, C. C., Jr., Hubbard and Company, New York, N. Y.
Warren, J. E., Nilsson Electrical Laboratory, New York, N. Y.
Weston, S., Federal Telegraph Company, Newark, N. J.
Winter, H. F., Bell Telephone Laboratories, Incorporated, New York, N. Y.
Yakman, J. V., Otis Elevator Company, Yonkers, N. Y.
Yingling, G. L., Jr., Underwriters' Laboratories, Incorporated, New York, N. Y.

4. Southern

Alley, R. E., Jr., University of Richmond, Richmond, Va.
Baker, W. W., Memphis Light, Gas and Water Division, Memphis, Tenn.
Bivins, A. C., Jr., Florida Power and Light Company, Miami, Fla.
Blanchard, E. I., Louisiana Power and Light Company, New Orleans, La.
Brice, J. R., Tampa Electric Company, Tampa, Fla.
Delbridge, C. A., Aluminum Company of America, Alcoa, Tenn.
DiVincenzo, A. P., Tennessee Valley Authority, Knoxville, Tenn.
Duling, H. B., Georgia School of Technology, Atlanta, Ga.
Fortune, R. W., Virginia Public Service Company, Clifton Forge, Va.
Fritz, C. J., South Carolina Electric and Gas Company, Parr, S. C.
Gaylord, H. R., Florida Power and Light Company, Miami, Fla.
Gilkeson, W. R., Tennessee Valley Authority, Chattanooga, Tenn.
Hansen, J. W., Jr., Newport News Shipbuilding and Dry Dock Company, Newport News, Va.
Hicks, W. L., Jr., The Le Tourneau Company of Georgia, Toccoa, Georgia.
Higgins, R. W., Georgia Power Company, Augusta, Ga.
Hipp, W. N. (Member), Duke Power Company, Hickory, N. C.
Huber, I. L., Tennessee Valley Authority, Tupelo, Miss.
Jones, L. G., General Electric Company, Jackson, Mississippi.
Kingsland, R. L., Jr., United States Army, 62nd Field Artillery, A.P.O. 37, Camp Shelby, Miss.
Leach, H. R., Chattanooga Electric Power Board, Chattanooga, Tenn.
Petersen, G. C., United States Army, Fort Knox, Ky.
Randle, R. O., Solvay Process Company, Hopewell, Va.
Robinson, J. P., Tennessee Valley Administration, Wheeler Dam, Ala.
Scruggs, D. W., Aluminum Company of America, Alcoa, Tenn.
Shipley, C. S., Tennessee Valley Authority, Chattanooga, Tenn.
Shoaf, J. R., United States Army, Armored Force Replacement Center, Fort Knox, Ky.
Simmons, B., Jr., Western Electric Company, New Orleans, La.
Somis, E. E. J., Sewerage and Water Board of New Orleans, New Orleans, La.
Wiggins, C. Q., Jr., Aluminum Company of America, Alcoa, Tenn.
Woods, A. F., Tennessee Valley Authority, Chattanooga, Tenn.

5. Great Lakes

Abolin, T. W., Indiana and Michigan Electric Company, Mishawaka, Ind.
Andersmann, R. J., Commonwealth Edison Company, Chicago, Ill.
Anderson, K., Indiana and Michigan Elevator Company, South Bend, Ind.
Anderson, R. E. (Member), Delta-Star Electric Company, Chicago, Ill.
Bauman, C. B., Commonwealth and Southern Corporation, Jackson, Michigan.
Bleaden, S., Goldberg and O'Brien Electric Company, Chicago, Ill.
Brickman, B. A., Western Electric Company, Incorporated, Chicago, Ill.
Burge, W. L., Wisconsin Michigan Power Company, Appleton, Wis.
Cecil, J. B., Wisconsin Electric Power Company, Milwaukee, Wisconsin.
Cohen, J. I., Electromotive Corporation, La Grange, Illinois.
Colby, R. L., Jr., Cutler-Hammer, Incorporated, Milwaukee, Wisconsin.
Cosen, V. B., Powers Regulator Company, Indianapolis, Ind.
Davidson, C. S., Yale and Towne Manufacturing Company, Chicago, Ill.
Dembinski, L., Fansteel Metallurgical Corporation, Chicago, Ill.
DeFew, R. T., Radio Station WGN, Incorporated, Chicago, Ill.
Derus, H. M., Waukesha Motor Company, Waukesha, Wis.
Drummond, V. L., General Motors Corporation, Detroit, Mich.
Firmin, G. P., Indiana and Michigan Electric Company, South Bend, Indiana.
Foxworthy, M. K., Jr., Indianapolis Power and Light Company, Indianapolis, Ind.
Gillis, N. W., Bendix Aviation Corporation, Detroit, Mich.
Griffith, D. J., Eagle Signal Corporation, Moline, Ill.
Haller, P. E., Commonwealth Edison Company, Chicago, Ill.

Hanson, O. B. (Member), Commonwealth Edison Company, Chicago, Ill.
Harris, A. J., Fisher Body Corporation, Detroit, Mich.
Hauber, P. C., United Light and Power Service Company, Davenport, Iowa.
Herman, A. E., Cutler-Hammer, Incorporated, Milwaukee, Wisconsin.
Herrmann, J. A., Bull Dog Electric Products Company, Detroit, Mich.
Hickman, F. J., Eastern Indiana Telephone Company, Winchester, Ind.
Holland, E. B., United Light and Power Service Company, Davenport, Iowa.
Huston, E. F., J. D. Adams Manufacturing Company, Indianapolis, Ind.
Jost, L. J., 2245 E. Kirby, Detroit, Michigan.
Keeler, A. R., 3rd, Walker and Company, Detroit, Michigan.
Kiefert, H. W., Commonwealth Edison Company, Chicago, Ill.
Knudsen, A. L., Navy Department, United States Government, Detroit, Mich.
Kreydich, W., Kellogg Switchboard and Supply Company, Chicago, Ill.
Krug, W. J., Electro-Motive Corporation, La Grange, Ill.
LaHue, D. F., Western Union Telegraph Company, Chicago, Ill.
Leonard, P. M., Illinois-Carnegie Steel Company, Chicago, Ill.
Leske, B. A., Divane Brothers Electric Company, Chicago, Ill.
Major, W. R., Jr., Line Material Company, Milwaukee, Wisconsin.
McLaughlin, D. J., Montgomery Ward and Company, Chicago, Ill.
Otto, H. W., Public Service Company of Northern Illinois, Chicago, Ill.
Parker, L. D., 120 East 13th Street, Traverse City, Michigan.
Rego, D. S., Jr., United States Army Air Corps, Chanticleer Field, Rantoul, Ill. (for mail: 902 Locust Street, Fall River, Mass.).
Robb, S. J., Commonwealth Edison Company, Chicago, Ill.
Ryan, W. J., Jr., Charlestown Ordnance Construction, E. I. du Pont de Nemours & Company, Charlestown, Ind.
Saltz, L. W., H. E. Beyster Corporation, Detroit, Michigan.
Schall, G. E., Jr., Underwriters' Laboratories, Chicago, Ill.
Sebring, P. B., Zenith Radio Corporation, Chicago, Ill.
Shapiro, H. M., Public Utility Engineering and Service Corporation, Chicago, Ill.
Shay, E., Carnegie-Illinois Steel Corporation, Gary, Ind.
Shouskey, E., 2725—24 Street, Detroit, Mich.
Smale, J. H., Indianapolis Power and Light Company, Indianapolis, Ind.
Spurrell, M. P., Bull Dog Electric Products Company, Detroit, Mich.
Stanford, J. H., Jr., Caterpillar Tractor Company, Peoria, Ill.
Steidinger, D. R., Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin.
Stradling, R. B., Westinghouse Electric and Manufacturing Company, Indianapolis, Ind.
Sullivan, E. F., Zenith Radio Corporation, Chicago, Ill.
Tayler, W. L., Commonwealth Edison Company, Chicago, Ill.
Thompson, C. B., Automatic Electric Company, Chicago, Ill.
Tierney, W. E., Rockbestos Products Corporation, Chicago, Ill.
Tracy, W. F., Illinois Bell Telephone Company, Chicago, Ill.
Wade, S. R., General Electric Company, Fort Wayne, Indiana.
Warnek, R. G., Wisconsin Telephone Company, Madison, Wis.
Weichsel, G. H., Western United Gas and Electric Company, Aurora, Ill.
Wellbaecher, C. O., Allis-Chalmers Manufacturing Company, Milwaukee, Wis.
Weissert, R. K., General Motors Corporation, Flint, Michigan.
Youngberg, M. D., Commonwealth Edison Company, Chicago, Ill.

6. North Central

Kettering, C., Fairbanks-Morse and Company, Omaha, Nebraska.
Klosterman, P. C., South Dakota State College, Brookings, S. D.
Kurie, C. W., Jr. (Member), City of Colorado Springs, Colorado Springs, Colo.

7. South West

Armbruster, W. R., Laclede Gas Light Company, St. Louis, Mo.
Ball, W. A., Jr., Gulf States Utilities Company, Beaumont, Texas.
Bohnenblust, C. E., Southwestern Bell Telephone Company, Wichita, Kansas.
Bryant, R. B., Wagner Electric Corporation, St. Louis, Mo.
Chafetz, A. B., City of Austin, Austin, Texas.
Cross, R. K., Emerson Electric Company, St. Louis, Mo.
Dibble, E. F., Grand River Dam Authority, Vinita, Okla.
Dinsmore, J. H., Navy Department, Consolidated Steel Company, Orange, Texas.
Edwards, F. A., Company F, 137 Infantry, Camp Robinson, Little Rock, Arkansas.
Ewan, A. W., U. S. Engineer Office, Little Rock, Ark.
Fell, W. J., Holway and Neuffer, Tulsa, Oklahoma.
Fritsche, L. P., Amerada Petroleum Corporation, Tulsa, Okla.
Hamilton, J. F., Stamolind Oil and Gas Company, Hays, Kansas.
Hobbs, E. G., 349th Field Artillery, Fort Sill, Oklahoma.
Howard, R. L., Texas-New Mexico Utilities Company, Lubbock, Texas.
Hoyt, W. L., Petty Geophysical Engineering Company, San Antonio, Texas.
Kemper, J. T., Wagner Electric Corporation, St. Louis, Mo.
Knaul, J. E., Transcontinental and Western Air, Incorporated, Kansas City, Mo.
Martin, W. L., III, Emerson Electric Manufacturing Company, St. Louis, Mo.
Maxey, W. D., United States Army, 63rd C. A., Ft. Bliss, Texas.
Maze, R. O., Wagner Electric Corporation, St. Louis, Mo.
Metcalf, J. W., Chicago Wilmington and Franklin Coal Company, St. Louis, Mo.
Nafe, H. G., Jr., Century Electric Company, St. Louis, Mo.
Patrick, J. M., Texas-New Mexico Utilities Company, Clovis, New Mexico.
Potthoff, W. J., Emerson Electric Manufacturing Company, St. Louis, Mo.
Ruff, A. S., American Telephone and Telegraph Company, Wichita, Kansas.
Shaw, L. E., S. B. Wadley, Consulting Engineer, Bingfisher, Okla.
Shotliff, L. A., Washington University, St. Louis, Mo.
Sontag, R. E., Okonite Company, St. Louis, Mo.
Vasconcellos, J. A., Jr., 3rd Aircraft Warning Company, United States Army, Fort San Houston, Texas.
White, R. N., Transcontinental and Western Air Incorporated, Kansas City, Mo.
Widell, C. E., Wagner Electric Corporation, St. Louis, Mo.
Wimer, A. G., Jr., United States Engineers, Galveston, Texas.

8. Pacific

Ahrens, F. J., Electrical Facilities, Incorporated, Emeryville, Calif.
Allen, H. S., Jr., Photo and Sound, Incorporated, San Francisco, Calif.
Biggs, H. C., General Electric X-ray Corporation, San Francisco, Calif.
Bloom, W. B., Pacific Gas and Electric Company, Oakland, Calif.
Borgeson, L. G., Fox West Coast Theatres, Pasadena, Calif.
Brewer, A. F., Square D Company, Los Angeles, Calif.
Carlton, R. E., Division of Water Resources, Sacramento, Calif.
Carson, D. B., California Institute of Technology, Pasadena, Calif.
Davis, H. S., Lane-Wells Company, Bakersfield, Calif.
Ferry, T. R., Pacific Gas and Electric Company, Shasta County, Calif.
Garretson, H. W., U. S. Navy Department, Mare Island, Calif.
Hamilton, O. W., Signal Corps, United States Army, Hamilton Field, Calif.
Kalb, H. N (Member), Pacific Gas and Electric Company, San Francisco, Calif.
Keyser, J. H., Jr., Sterling Electric Motors, Incorporated, Los Angeles, Calif.
Kilkenny, J. J., Bethlehem Steel Company, San Francisco, Calif.
Kipp, R. B., Southern California Gas Company, Los Angeles, Calif.
Mann, D. O., Navy Department, United States Government, San Francisco, Calif.
McNulty, C. H., Citizens Utilities Company, Nogales, Arizona.
Moorhead, G. H., Jr., Southern California Gas Company, Los Angeles, Calif.
Mueller, E. H., 903 California Street, Eureka, Calif.
Nelson, N. H., Lockheed Aircraft Corporation, Burbank, Calif.
Pursley, R. M., Westinghouse Electric and Manufacturing Company, Los Angeles, Calif.
Serduke, J. T. (Member), 464 California Street, San Francisco, Calif.
Somerfeld, H., City of Los Angeles, Department of Water and Power, Los Angeles, Calif.
Wells, L. A., Jr., Pelton Water Wheel Company, San Francisco, California.
Witzig, R., Bethlehem Steel Company, Terminal Island, Calif.
Yadon, J. M., Westinghouse Electric and Manufacturing Company, San Francisco, Calif.

9. North West

Bryant, W. N., Boeing Aircraft Company, Seattle, Wash.
Chambers, W. R., Washington Water Power Company, Spokane, Wash.
Childers, J. W., Pacific Power and Light Company, Walla Walla, Wash.
Crandall, R. K., California Oregon Power Company, Medford, Oregon.
Hartley, H. E., Idaho Power Company, Emmett, Idaho.
Love, E. B., Idaho Power Company, Caldwell, Idaho.
Lundborg, C. J., Anaconda Copper Mining Company, Great Falls, Mont.
Murphy, T. H., Coast and Geodetic Survey, Seattle, Washington (for mail: 2203 N. Emerson Street, Portland, Oregon).
Nungester, J. L., Washington Water Power Company, Spokane, Wash.
O'Leary, L. R., Puget Sound Power and Light Company, Seattle, Wash.
Ranzenbach, O. F., Washington Water Power Company, Spokane, Wash.
Smith, G. G., Seattle Lighting Department, Seattle, Washington.
Spencer, J. H., University of Washington, Seattle, Wash.
Spillman, W. E., Portland General Electric Company, Portland, Oregon.
Torget, A. O., Boeing Aircraft Company, Seattle, Wash.
Ward-Davis, G., Puget Sound Power and Light Company, Seattle, Washington.
Wiscombe, L. E., Wasatch Oil Refining Company, Woods Cross, Utah.

10. Canada

Andrews, S. C., Pacific Mills, Limited, Ocean Falls, B. C.
Cline, J. C., Hydro Electric Power Commission of Ontario, Toronto, Ont.
Elliott, H. W., Research Baterprises, Limited, Leaside, Ont.
Fraresso, M., Canadian General Electric Company, Peterboro, Ont.
Gibbons, R. S., Bell Telephone Company of Canada, Toronto, Ont.
Hopkins, H. A., Amalgamated Electric Corporation, Toronto.
Mah, H. G., Canadian Line Materials Limited, Toronto, Ont.
McLean, A. F., Fraser-Brace Engineering Company, Transcona, Manitoba.
Murphy, H. J., Barrie Public Utilities, Barrie, Ont.
Woolgar, C. E. (Member), Northern Electric Company, Limited, Montreal.

Total, United States and Canada, 481

Elsewhere

Andrade, H. Z., Construction Quartermaster, United States Army, Canal Zone.
Craig, D. H. C. (Member), English Electric Company Limited, Bristol, England.
Frugtniet, R. M. L., Johnson and Phillips Limited, Charlton, London, England.
Mayol, F. C., Puerto Rico Telephone Company, Santurce, Puerto Rico.
Purcell, H. C., The Hawaiian Electric Company, Limited, Honolulu, Hawaii.
Setala, V. A., Navy Department, Pearl Harbor, Hawaii.
Smith, J. R., Panama Canal, Balboa Heights, Canal Zone.
Valladares, J. A., Cuban Telephone Company, Havana, Cuba.
Villageliu, A. B., General Electric of Cuba, Edificio "La Metropolitana" Havana, Cuba.

Total, elsewhere, 9

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the addresses as they now appear on the Institute record. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

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Freed, John H., Olson Construction Co., 416 W. 7th St., Lincoln, Nebr.
Gregory, Herbert Scott, Y. M. C. A., Schenectady, N. Y.
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Kryder, Paul A., 1527 North 52nd., Milwaukee, Wis.
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McCown, Joe F., 215 Naval Ave., Bremerton, Wash.
Myers, W. H., 505 West Seaside, Long Beach, Calif.
Radcliffe, J. H., 334 Reid St., Peterboro, Ont., Can.

16 Addresses Wanted

Of Current Interest

Electric Power and the National Defense Program

FROM a variety of sources, the following items reflect various aspects of the power supply situation in the United States as it relates to the national defense program.

FEDERAL POWER COMMISSION PREDICTS POWER REQUIREMENTS

In a report recently issued, the Federal Power Commission forecasts probable future requirements for electric power, by power supply areas, through 1942. "In approximately half of the power supply areas," the report states, "there is installed or scheduled for operation this year, sufficient capacity to supply the anticipated demand for 1941. In other areas, it appears that anticipated demands can be met by encroaching on reserves, or by additional capacity made available through interconnections with systems in adjacent areas. In certain hydro areas, the situation can be met if favorable stream flow conditions prevail."

The following conclusions, taken from the report, emphasize the need for continued study and planning to assure the country against shortage of power:

"1. The demand for power is growing more rapidly than the utility systems expected. Their December 1940 demand of 27,752,856 kw exceeded their September 1940 demand by 2,609,154 kw. This increase exceeded by 472,440 kw, or 22 per cent, the estimates in the September reports of the utilities.

"2. In nine important war-material areas (New England, up-state New York, Philadelphia–New Jersey, western Pennsylvania, Ohio, Michigan, Alabama and Georgia, north central Texas, and the Bonneville–Grand Coulee area) the September reports of the utility systems estimated the increase in demand for power for the three following months at 797,806 kw. They experienced an actual increase of 1,223,880 kw, or 53 per cent more than they had estimated. In some of these areas the increases were approximately double those anticipated.

"3. Margins of error of this order in planning to meet power demands two years hence, when the expanding defense program will be pressing the country's generating capacity, would mean serious power shortages such as threatened the defense effort in 1918.

"4. The volume of new capacity on order and the resulting effect on the future net assured capacity is changing rapidly. Between September and December, 1940, the additional generating capacity for installation by December 1942 was increased by 906,500 kw through orders for additional generators, arrangements for expediting existing orders, and orders for new boilers.

"5. Approximately 900,000 kw of capacity in addition to that now on order should be provided by late 1942 to insure against power shortages in a number of areas in that year.

"6. In certain areas, notably New England, Ohio, Missouri, western Wisconsin, and eastern Minnesota, the new orders since September will bring the net assured capacity, as of December 1942, to approximately the level which the estimates of defense load show should be planned for.

"7. In other areas, notably up-state New York and the Georgia–Alabama area, considerable additions to capacity planned for 1942 still fall short of providing sufficient capacity to serve the loads which should be planned for. In the case of New York, increased transmission capacity connecting the up-state systems with the metropolitan area would be of great assistance in meeting the 1942 situation.

"8. The important areas where still further additions to capacity are likely to be needed by December 1942 include those listed above in paragraph 7 and the following areas: Pittsburgh and vicinity, Virginia, Arkansas–Louisiana, and the northern California–Oregon–Nevada area."

Complete copies of the report, which is entitled "Electric Power Requirements and Supply in the United States—December 1940", may be obtained at 50 cents each, from the Federal Power Commission, Washington, D. C.

NETWORK OF LITTLE TVAS PLANNED

Power needs of the defense program are stimulating the efforts of the Government to establish public power development projects, like the Tennessee Valley Authority, in other sections of the United States. An agreement between the United States and Canada on the St. Lawrence seaway and power project was signed at Ottawa March 19, 1941, and is awaiting action by Congress. Legislation now awaiting enactment will provide further development of the Columbia River basin in the northwest, and of the Arkansas River basin in the midwest. An additional appropriation also has been requested for an expansion of TVA activities.

In addition to the activities of these new proposed projects, work is being speeded up and generating capacities increased at other Government power units. Plans are being pushed to rush completion of the Shasta dam project in California, and to provide additional generating capacity at Boulder, Bonneville, and Grand Coulee dams. At Parker Dam, original schedule calls for power generation by 1950, but the first generator is expected to be placed in operation during 1941.

CHAMBER OF COMMERCE COMMITTEE REPORTS ON GOVERNMENT PROJECTS

Opposition to the setting up of regional power authorities in various parts of the country and, more specifically, to the St. Lawrence power project, is expressed in a report by the committee on natural resources production of the Chamber of Commerce of the United States which will be submitted to the membership for consideration at the forthcoming annual meeting of the organization.

The Chamber's committee draws attention to the fact that plans are maturing for the resumption of the regionalization program. In connection with the St. Lawrence seaway and project, on which an agreement with Canada has since been made, the report stated:

"A proposal is also prominent to undertake at once power development on the international section of the St. Lawrence River as a defense emergency measure. More electric power in the St. Lawrence is the primary defense purpose being put forward for this development. For the immediate future and before a new St. Lawrence power project can possibly be completed and ready for operation, new power demands arising in both Canadian and American sections of the St. Lawrence area must be met by other programs.

"It is obvious that the St. Lawrence power project cannot be justified, either in Canada or in the United States, for electric power for defense industries. The growing needs of defense industries in the St. Lawrence region, as elsewhere, are of first importance and they must be met by expansion programs other than the St. Lawrence development now proposed. It is vitally necessary that all additions to present plants should be made as planned and in time to provide electric energy as needed. This need should reach its peak long before new power can be supplied by the proposed St. Lawrence development.

"The companies which have to install the needed additional capacity for the immediate years ahead should be free from apprehension as to the consequent unfair use of government power in ways destructive of investments which are needed for defense."

The committee points out that plans are also under way for the conversion of projects in other areas into regional authorities, including the Columbia River area and the Central Valley in California. It continues:

"Aside from other considerations, it would be unwise at this time, when the country is faced with necessity of heavy outlays for national defense, to divert capital, man-power, engineering talent, construction and manufacturing equipment to projects undertaken ostensibly for national defense that would not afford effective means of meeting present national defense requirements."

In a report on electric power supply, the Chamber's committee finds that by the time defense production goes into high gear existing facilities and additional facilities now planned will be ample to meet all power demands. The committee says:

"Industrial activity in 1940, stimulated by foreign war and home defense, made substantial new demands for electric power from utility systems. Throughout the country these utilities have been able to meet almost every demand with surprising promptness and efficiency. During the year, 1,790,000 kw of new generating capacity were added. The new capacity definitely to be added this year is 3,420,000 kw, exceeding by 1,000,000 kw the greatest previous record in the industry's history, that set in 1930 when 2,490,000 kw were added."

MORE POWER ON PACIFIC COAST

The $30,000,000 Feather River project of the Pacific Gas and Electric Company was approved February 20 by the Federal

Power Commission. Plans call for the construction of two hydroelectric plants to have a combined total capacity of 203,000 horsepower, which is expected to be sufficient to meet any power requirements for the region until the spring of 1945. The new plants will be known as the Cresta and Pulga plants. Work on the former is to begin in one month and to be completed by January 1, 1943; on the latter to be started in six months and to be completed by July 1, 1943. This project is the final link in a $50,000,000 program begun several years ago by the company, and including three steam plants on the bay shore in Contra Costa County, with a combined output of 60,000 horsepower. One of these plants has been completed and the other two are under construction. Work also is in progress on a 28,000 horsepower hydroelectric plant at Dutch Flat in Placer County.

PROGRESS ON SANTEE-COOPER PROJECT

Power production is expected to begin at the Santee-Cooper hydroelectric and navigation project in South Carolina by mid-October 1941. Construction work was begun in March 1932, and the project is being built by the South Carolina Public Service Authority. It includes two dams, one 7 miles long, including a 34,000-foot spillway, and the other 2 miles long. The reservoir will cover approximately 155 square miles.

Strategic Materials and the Defense Program

Government officials are viewing with concern the possibility that American isolation may become an economic fact instead of a theory of foreign policy, according to an article in the February 28, 1941 issue of *United States News*. "In recognition of this possibility," the article continues, "steps are being taken to insure the defense program and American industry an adequate supply of raw materials that now come from abroad.

"Secretary of Commerce Jesse H. Jones has announced plans to build a tin smelter in this country. The President has authorized industry to dip into Government stock piles of tungsten. Ships carrying 25,000 tons of rubber are docking each month at American ports. The Office of Production Management is surveying opportunities for using substitutes for such vital defense metals as steel and aluminum.

Tension in the Orient adds to the worries of procurement officials, for from the Far East come rubber, tin, tungsten, manila hemp, silk, mica, quinine, copra, spices, and vegetable oils. Nearly all of these items are listed as strategic materials by the War Department—materials that are not now obtained from domestic sources. Threatened war with Japan thus raises these questions: Will these vital supplies be shut off, and can American war industries operate if they are shut off?

The fact is that the United States, with the Caribbean area and Canada to draw upon, has little to worry about. American industry and American explorers are finding the answer to most raw material problems. If war should come within the next few months, uncomfortable adjustments might have to be made by civilians, but few doubt that America's war machine could be fed. In the long run, a self-contained America is viewed as distinctly possible."

As part of the program to speed domestic production of tungsten, a research engineer at the Westinghouse Lamp Division, Bloomfield, N. J., makes a test run on domestic tungsten ores.

Training Program of Signal Corps

The Signal Corps of the United States Army is preparing to set in motion at high speed a broad-gauged program of training hundreds of officers and approximately 24,000 enlisted men this year at its Fort Monmouth, N. J. Signal School to form the communications "backbone" of the greatly increased American army now being assembled for national defense, according to an article by Roland C. Davies in the March 1941 issue of *Telegraph and Telephone Age*. The article continues:

"The Fort Monmouth School is the keystone of the Army's training in communications activities since the Signal Corps co-ordinates the communications services for the entire Army and either conducts the instruction activities or trains the officer and noncommissioned personnel of the other branches of the Army to carry on the training programs of the different divisions. Besides the extensive Fort Monmouth School activities, communications training is conducted in the unit communications training centers in each Corps area so as to instruct the specialists and personnel for the Infantry, Cavalry, and Armored Divisions. In each Army area there is also a communications school. The Air Corps, likewise, has its own communications training program and schools which are manned by Air Corps communications officers. But throughout the Army the Signal Corps' operations, methods, and procedure form the foundation for all training activities.

Defense Production Facilities Surveyed

The first interim report on the nation-wide survey of portential defense production facilities recently was issued by Walder D. Fuller, president of the National Association of Manufacturers, to the 150 state manufacturers' associations co-operating in the survey. "Plants and machine tools, ready and willing to handle anything from gun boring to parachute manufacture," have been located through the survey, Mr. Fuller reports.

"The majority of the plants now registering their facilities for defense," the report continues, "are not among the 10,000 major corporations already surveyed by Army and Navy departments for possible prime contract purposes; these plants now being revealed are the small contractors who might be geared into this vast production job as subcontractors as quickly as the engineering problems can be solved. . . . These manufacturers all over the nation are doing more than sub-contracting defense orders; they are contributing threefold to the stability of our nation during a period of tremendous industrial stress:

"1. By utilizing our existing machine tools, plants, and shipyards, we remove the need for building others, and overexpanding our plant needs.

"2. By making known and ready those tools and yards, contracts may be placed which will employ local labor.

"3. By keeping that labor employed and at home, we will complete the full social and economic advantage to your community, and to the nation as a whole, by eliminating unnecessary migration of labor, and thus, the creation of housing crises."

ASME Discusses Defense. At a joint meeting held March 12–13, in Cleveland, Ohio, under joint auspices of the Army Ordnance Association and various committees and divisions of The American Society of Mechanical Engineers, various aspects of the national defense program were discussed in a well planned and co-ordinated program. Sessions were held on the following topics: Speeding tank manufacture, ammunition manufacture, aviation manufacture, gauging, training and recruitment of industrial personnel, and subcontracting. Papers were presented by representatives of some of the leading manufacturers of defense materials, by representatives of the United States armed forces, and others.

Library Facilities for National Defense. A "Guide to Library Facilities for National Defense" has been prepared by the joint committee on library research facilities for national emergency of the American Library Association. Special, general, and college libraries are included in the 235-page survey of library resources on subjects relating to defense. The material is arranged according to subject, with subdivisions under the main subject headings, and further organized by the geographical location of the libraries. A list of the libraries included, some 500 in number, is appended, as well as an index. The preliminary edition, edited by Carl L. Cannon and published typewritten photolithographic form, may be obtained from the American Library Association, Chicago, Ill.; price $1.25. Plans are in progress for a revised and augmented edition, which it is hoped will appear early in 1942.

Book Lists for Defense Training. A series of book lists to aid in the training of men for

defense work has been issued by the American Library Association in co-operation with the United States Office of Education. Five lists have been issued so far on the following topics:

The Shop's Library: Material Useful for Elementary Training, Iva Wintefield.

Industrial Training for National Defense, Charles M. Mohrhardt.

Aeronautic Training for National Defense, Paul Howard.

Engineering Defense Training, Harrison W. Craver and Harrison A. von Urff.

Military Training for National Defense, Florence S. Hellman.

Each list contains outlines of more than 100 books, pamphlets, and periodicals on its particular subject. Copies may be obtained from the American Library Association, Chicago, Ill., at 25 cents each; 10 copies $1.00; 25, $2.00; 50, $3.00; 100, $5.00.

FPC Issues Information on Generating Plants, Power Output

THE Federal Power Commission has issued a directory of electric generating plants in operation in the United States January 1, 1941, with a 27- by 42-inch map of principal generating plants and transmission lines, and also a wall map, 4½ by 7 feet. Copies of the wall map, at $2.50 per copy in two sections unmounted, or $5 per copy mounted, and of the directory and smaller map, at $1, may be obtained from the FPC, Washington, D. C. The directory lists all electric utility generating plants in the United States of 1,000 kw or more of installed capacity, classifying them by age, size, and type of prime mover. These 1,922 plants have an aggregate capacity of 39,503,445 kw and comprise more than 98 per cent of total central-station capacity in the United States. A summary of plants classified by states and by types of prime mover is presented in table I.

Information on power production, which reached an all-time high in 1940, also has been issued recently by the Commission. The preliminary estimate of 144,965,000,000 kilowatt-hours far exceeds the highest annual total heretofore recorded and is approximately 11 per cent more than was produced during 1939. Of the total energy reported, 2,719,000,000 kilowatt-hours were produced by electric railroads, electric railways, and other miscellaneous plants.

The production of electric energy by use of water power amounted to 47,742,000,000 kilowatt-hours, or approximately 8 per cent more than was produced by this means in 1939. This represents 33 per cent of the total output for the year. The average for the 21-year period from 1920 to 1940 is 36 per cent of the total.

The total installed capacity of generating plants available for service as of December 31, 1940, was 41,576,000 kw. This represents a net increase of approximately 1,258,000 kw during 1940, or 3.1 per cent more than was reported for the period ending December 31, 1939.

Coal consumption increased approximately 16 per cent, or about 7,000,000 tons.

Oil consumption decreased 4 per cent, or about 700,000 barrels. The amount of gas consumed decreased more than 8,000,000,000 cubic feet, or 4 per cent. From these figures it is apparent that the increased production by use of fuel was accomplished by use of additional coal rather than gas or oil.

Tables II and III show for the United States and its divisions the annual production of electric energy by use of water power and by the use of fuels for the years 1939 and 1940, and the percentage change from 1939 to 1940 in the production of electric energy and the use of different fuels for such purpose. The information in the tables is preliminary and is based on the figures of production of electric energy previously published in the monthly reports issued during 1940. The output of central stations, both publicly and privately owned, electric railway plants, plants operated by steam railroads generating electric energy for traction, Bureau of Reclamation plants, and that part of the output of manufacturing plants which is sold are included in these data. Accurate data are received each month representing approximately 98 per cent of the output shown; the remaining 2 per cent of the output is estimated so that the data represent 100 per cent of the generation.

State Utility Regulation Reported by FPC. A report on "State Commission Jurisdiction and Regulation of Electric and Gas Utilities" has been prepared by the Federal Power Commission to meet administrative needs of Federal state agencies. The data

Table I. Electric Generating Capacity by States, January 1, 1941

(Plants of 1,000 Kw or More)

States	Hydro		Steam		Internal Combustion		Total	
	Number Plants	Total Capacity Kw	Number Plants	Total Capacity Kw	Number Plants	Total Capacity Kw	Number Plants	Total Capacity Kw
Alabama	12	751,283	13	243,810	1	1,528	26	996,621
Arizona	10	291,500	5	49,660	12	40,472	27	381,632
Arkansas	2	65,300	11	72,630	7	10,454	20	148,384
California	97	1,544,617	23	1,157,460	4	44,364	124	2,746,441
Colorado	13	60,310	19	182,285	3	6,209	35	248,804
Connecticut	9	83,250	12	531,340	1	1,100	22	615,690
Delaware			4	23,150	3	3,823	7	26,973
Dist. of Col.			2	305,000			2	305,000
Florida	2	13,713	23	386,038	11	19,161	36	418,912
Georgia	21	335,940	15	137,400			36	473,340
Idaho	25	252,315			1	1,300	26	253,615
Illinois	10	51,893	52	2,559,640	5	9,601	67	2,621,134
Indiana	6	32,710	43	1,259,705	4	8,650	53	1,301,065
Iowa	6	116,900	35	447,970	25	40,425	66	604,295
Kansas	1	3,000	31	434,350	23	35,486	55	472,836
Kentucky	3	110,860	18	246,075	1	1,445	22	358,380
Louisiana			6	368,600	14	27,424	20	396,024
Maine	31	227,823	5	67,000			36	294,823
Maryland	2	271,200	9	399,100	3	4,200	14	674,500
Massachusetts	18	156,291	31	991,840	4	7,743	53	1,155,874
Michigan	60	268,129	26	1,587,575	12	22,766	98	1,878,470
Minnesota	20	116,740	39	424,075	10	15,836	69	556,651
Mississippi			13	46,370	2	3,600	15	49,970
Missouri	5	157,800	29	583,923	16	26,920	50	768,643
Montana	14	313,990	3	10,800	1	1,000	18	325,790
Nebraska	8	132,238	20	221,428	13	19,381	41	373,047
Nevada	5	502,400			1	1,870	6	504,270
New Hampshire	19	226,510	5	80,250			24	306,760
New Jersey			14	1,211,750	1	1,810	15	1,213,560
New Mexico	1	24,300	11	91,430	5	10,590	17	126,320
New York	99	1,111,564	40	3,896,100	4	18,228	143	5,025,892
North Carolina	27	699,591	15	470,250	3	5,200	45	1,175,041
North Dakota			13	79,913	4	5,409	17	85,322
Ohio	4	10,950	68	2,412,865	3	5,292	75	2,429,107
Oklahoma			19	319,102	14	26,074	33	345,176
Oregon	23	376,435	11	171,750	1	2,710	35	550,895
Pennsylvania	9	415,960	68	2,629,927	3	4,895	80	3,050,782
Rhode Island	1	1,000	4	263,700			5	264,700
South Carolina	20	508,860	7	135,800	1	1,458	28	646,118
South Dakota	2	2,500	8	48,850	8	13,713	18	65,063
Tennessee	10	386,253	12	190,690	1	1,183	23	578,126
Texas	15	100,580	44	938,440	25	53,341	84	1,092,361
Utah	20	79,400	2	59,750	3	7,205	25	146,355
Vermont	27	146,490	4	10,400			31	156,890
Virginia	19	172,940	13	385,575	4	5,671	36	564,186
Washington	34	791,112	11	202,570			45	993,682
West Virginia	8	99,640	9	587,440	1	3,200	18	690,280
Wisconsin	34	240,430	27	719,954	6	11,188	67	971,572
Wyoming	5	46,150	8	26,910	1	1,013	14	74,073
Totals	757	11,299,867	900	27,670,640	265	532,938	1,922	39,503,445

Table II. Annual Production of Electric Energy in the United States, 1939 and 1940

(Millions of Kilowatt-Hours)

Geographic Division	Total			By Use of Water Power			By Use of Fuel		
	1939	1940	Change (Per Cent)	1939	1940	Change (Per Cent)	1939	1940	Change (Per Cent)
United States	130,336	144,965	+11	44,022	47,742	+ 8	86,314	97,223	+13
New England	8,350	8,974	+ 7	2,876	2,772	− 4	5,474	6,202	+13
Middle Atlantic	32,970	36,385	+10	7,335	7,721	+ 5	25,635	28,664	+12
East North Central	29,995	33,595	+12	2,883	2,857	− 1	27,112	30,738	+13
West North Central	7,860	8,478	+ 8	1,865	1,694	− 9	5,995	6,784	+13
South Atlantic	15,190	17,623	+16	5,562	5,751	+ 3	9,628	11,872	+23
East South Central	6,968	8,465	+21	5,057	6,055	+20	1,911	2,410	+26
West South Central	6,980	7,435	+ 7	239	319	+33	6,741	7,116	+ 6
Mountain	7,492	8,537	+14	6,017	6,788	+12	1,475	1,709	+20
Pacific	14,531	15,473	+ 6	12,188	13,805	+13	2,343	1,668	−29

Table III. Annual Consumption of Fuels in Generating Electric Energy, 1939 and 1940

Geographic Division	Coal (Thousands of Short Tons)			Oil (Thousands of Barrels)			Gas (Millions of Cubic Feet)		
	1939	1940	Change (Per Cent)	1939	1940	Change (Per Cent)	1939	1940	Change (Per Cent)
United States	46,223	53,405	+16	17,423	16,727	− 4	191,131	183,136	− 4
New England	2,340	2,915	+30	5,282	4,305	−18	0	0	
Middle Atlantic	14,464	16,788	+16	5,025	3,983	−21	4,452	461	−90
East North Central	17,779	20,008	+13	334	424	+27	16,003	12,949	−19
West North Central	3,198	3,611	+13	1,236	1,402	+13	41,572	43,215	+ 4
South Atlantic	5,310	6,466	+22	3,541	3,979	+12	3,681	4,842	+32
East South Central	1,517	1,891	+25	91	162	+78	7,458	6,392	−14
West South Central	929	818	−12	679	750	+10	85,301	91,458	+ 7
Mountain	776	908	+17	630	934	+48	9,503	9,804	+ 3
Pacific	10	0		605	788	+30	23,161	14,015	−39

show the nature and extent of regulation by States under existing laws, and have been checked by the State commissions. Copies of the report, FPC S-10, may be obtained from the Federal Power Commission, Washington, D. C.; price 25 cents.

FPC Reports on Electric Bills. The Federal Power Commission has issued a report showing, in the form of typical net monthly bills, electric rates as of January 1, 1941, for residential, commercial light, commercial power, and industrial service in the 199 cities in the United States with populations of 50,000 or more. Copies of the report may be obtained from the Federal Power Commission, Washington, D. C.; price ten cents.

Positions to Be Filled Through Civil Service Examination

Notice of the following positions, which will be filled through civil service examinations, is published here as a service to members of the Institute. Application forms and full information as to requirements for examinations may be obtained from the secretary of the Board of United States Civil Service Examiners at any first- or second-class post office, or from the United States Civil Service Commission, Washington, D. C.

Chemical Engineers. Various grades, salaries ranging from $2,600 to $5,600 a year, less the retirement deduction of 3½ per cent. Engineers with experience in strategic mineral research are especially needed by the Bureau of Mines, Department of the Interior. The Regional Research Laboratories of the Department of Agriculture need persons experienced in the industrial utilization of surplus agricultural products. Separate employment lists will be established for positions in various specialized branches of chemical engineering such as fuels, foods, petroleum production, and plastics. Applicants must have completed a four-year college course with major study in engineering. Professional experience in chemical engineering is also required. Appointees will perform engineering work in such fields as pilot plant investigation, design and installation of equipment, and correlation of research data in the specialized branches of chemical engineering in which the appointments are made. Applications will be rated as received at the Commission's Washington office, until further notice.

Co-ordinators of Construction Inspection, United States Maritime Commission. Salary is $3,800 a year. Applicants may qualify in three optional branches: hull, electrical, and machinery. The maximum age limit is 65. Applicants must have had four years of practical experience of at least journeyman-mechanic grade on the construction or repair of ocean-going vessels. Successful completion of college study in naval architecture or any branch of engineering may be used for part or all of this general experience. An additional four years of experience in supervisory capacity is required. Two years of the total experience must have been gained in construction work on new vessels, while the remaining experience may have been on repair of ocean-going steel vessels. Persons appointed will serve as head of the hull, electrical, or machinery units of the inspection branch of the Maritime Commission. They will act as liaison officers between the home office and shipyards at which vessel construction is under way in order to establish and maintain uniformly high standards of construction and of equipment installation. Applications will be rated as received at the Commission's Washington office until further notice. Qualified persons are urged to apply at once.

Superintendents of Construction. Several grades, salaries ranging from $3,200 to $5,600 a year, less a 3½ per cent retirement deduction. In general, the duties involve the direction of foremen, laborers, and mechanics on large construction projects. Appointees will inspect materials and workmanship to see that they conform to specifications and will organize men and materials for efficient construction operations. Competitors must have had progressive experience in the field of general construction. Part of this experience must have been as superintendent on large projects involving excavation, reinforced concrete, steel, wood, and masonry, and supervision of three or more foremen of different building or construction trades. Engineering courses completed at a college or technical institute may be substituted for part of the general experience. Applications will be rated as received until December 31, 1941.

Junior Engineers. Positions in any branch of engineering, salary $2,000 a year, less a 3½ per cent retirement deduction. Appointees will perform professional engineering work, including assisting in experimental research, design or testing of machinery, and testing and inspection of engineering materials. Separate employment lists will be established in each recognized branch of engineering. Competitors must have completed a four-year engineering course, except that senior students will be admitted under certain conditions. They will not have to take a written test, but will be rated on their education and will be given additional credit for graduate study in engineering or for engineering experience. Applications will now be rated as received at the Commission's Washington office until December 31, 1941. Qualified persons who do not have eligible ratings under previous junior-engineer examinations held by the Commission within the past year are urged to file their applications at once.

Aeronautical Engineering Inspectors, Navy Department. Salaries range from $1,620 to $2,000 a year, less the usual retirement deduction. Maximum age 65 years. Particular attention is called to the experience requirements. In general, applicants must have had experience in the inspection or testing of engineering materials to determine compliance with specifications or standards of manufacture. Mechanical experience such as in the manufacture of precision instruments may be substituted for part of the inspectional experience. Also, each year successfully completed in resident study in an engineering, metallurgical, or technological course may be allowed for part of the experience. There are five optional branches for which the experience need not have been acquired on aircraft work specifically: engines, mechanical parts, instruments, tools and gauges, and materials. Three other options in which persons may qualify are aircraft, aircraft propellers, and parachutes. For all options completion of a training course of the United States Office of Education in materials inspection and testing for making inspection of general mechanical engineering materials will be accepted for one year of the required inspectional or testing experience. Applications will be rated as received at the Commission's Washington office until further notice.

Laboratory Mechanics Experienced in Fuel Rating. Salaries from $1,620 to $2,000 a year, less the usual

retirement deduction. Appointments will be made at the National Bureau of Standards, Department of Commerce. Responsible experience in the operation, testing, or maintenance of internal-combustion engines including experience in rating fuels with a CFR engine is required. Persons appointed as laboratory mechanics in fuel rating will make routine and referee ratings of motor, aviation, and Diesel fuels using the ASTM-CFR engine, the CFR aviation engine, or the CFR Diesel engine. They will record and tabulate the test data based on their findings. The duties of these positions also include the inspection and overhaul of test engines, and the installation of test equipment. Applications must be filed at the Commission's Washington office not later than April 17, 1941.

Junior Engineering Draftsmen. Salary $1,440 a year. Applicants may qualify in these branches of drafting: aeronautical, architectural, civil, electrical, mechanical (machine design), structural, topographic, lithographic, and general. In addition to completing 14 units of high-school study, applicants must have completed one year's experience or education in drafting, or a course in drafting under the Federal Office of Education Defense Training Program. Applications must be filed at the Commission's Washington office not later than April 24, 1941.

Education • • •

The Biggest Job of American Higher Education

In his Phi Beta Kappa address for 1940 Doctor Robert A. Millikan, president of California Institute of Technology, said:

"Let the point be emphasized as strongly as possible that steering students away from an attempt to enter that higher educational system when they do not show any capacity for solving analytical problems with success is not only the most kindly but it is also one of the highest forms of civic duty, since the success of our democracy depends upon it. . . .

"But someone asks, 'What is to be done with the rest?' It is a most amazing thing that in the development of our American educational system so little attention has been paid to the making of any provision for *the apprenticeship training in industry* of our manual and commercial workers who must constitute a large fraction of our population. We are far behind the whole of Europe, England, Australia, and New Zealand in this respect. That is the reason so many of our skilled mechanics and other workers are imported from abroad. Fortunately within the past few years some of our educational agencies have been waking up to this problem, so that what is probably the greatest deficiency in the educational development of the United States is now being given some attention. In consequence what to do with the boy who wants to become a really skilled mechanic is now being attacked through the industrial-apprenticeship plan so well developed in other countries."

Organization of committees of engineers to counsel with high school boys, as a community duty as well as a professional service, is being encouraged by the Engineers' Council for Professional Development.

Radio Interference Conference. To inform radio engineers, service men, amateurs, public service interference "trouble shooters", and others of the sources of radio interference and the possibilities of correction, the University of Illinois, Urbana, is holding a conference May 10, 1941. Topics to be considered by speakers and in panel discussions will include the generation of combination frequencies in a nonlinear element, diathermy interference, receiver design to minimize strong signal interference, interference between radio amateurs and broadcast listeners, adjustment of transmitters to reduce spurious emissions, reduction of appliance interference.

Iowa Management Course. A special three-week course on production planning, time and motion study, and related management problems is being presented for the third time June 9–27, 1941, by the University of Iowa. Planned for executives, engineers, and others interested in such training, the course is under the direction of Ralph M. Barnes, professor of industrial engineering. He will be assisted by six other members of the University faculty and eight visiting engineers and managers who will conduct forums.

Advance Graduation Urged. Graduation of 1942 engineering classes at least three months in advance of the usual date to help supply the need for young engineers in the national defense program was recently advocated by President W. A. Hanley of The American Society of Mechanical Engineers. He suggested that engineering schools continue courses through the summer of 1941 to permit graduation of the class of 1942 in February of that year. (*See also pages 175-7.*)

Other Societies •

Fire Underwriters Celebrate 75th Anniversary

Commemorating the 75th anniversary of the National Board of Fire Underwriters, founded in 1866, a nation-wide program is being planned to emphasize the contributions of fire insurance to national defense and the development of the United States. The program, under the direction of a special committee headed by W. E. Mallalieu, will culminate in commemorative events to be held in New York, N. Y., May 27–28, 1941. A. R. Small (M'37) president, Underwriters' Laboratory, Chicago, Ill., is a member of the national insurance committee co-operating in the effort.

"Recommended Practice of Street Lighting, 1940." The report on recommended street-lighting practice prepared by the committee on street and highway lighting of the Illuminating Engineering Society has been reprinted in bulletin form. The purpose of the publication, as stated, is to furnish the technical basis upon which effective street lighting may be designed, either as a co-ordinated plan for an entire street system or as a plan for any subdivision. Since the variety of conditions encountered makes it impracticable to set up specifications covering all situations, the bulletin is confined to fundamental principles and general specifications. Copies may be obtained from IES headquarters, 51 Madison Avenue, New York, N. Y.; price per single copy, 15 cents, discounts for quantity orders.

Future Meetings of Other Societies

American Institute of Chemical Engineers. Semi-annual meeting, May 19–21, 1941, Chicago, Ill.

American Mathematical Society. 379th meeting, May 2–3, 1941, Washington, D. C.

American Physical Society. 241st meeting, May 1–3, 1941, Washington, D. C.

242d meeting, June 20–21, Providence, R. I.

243d meeting (Pacific Coast), June 1941, Pasadena, Calif.

American Society for Testing Materials. 44th annual meeting, June 23–27, 1941, Chicago, Ill.

American Society of Civil Engineers. Spring meeting, April 23–25, 1941, Baltimore, Md.

Annual convention, July 23–25, 1941, San Diego, Calif.

American Society of Mechanical Engineers. Spring meeting, March 31–April 3, 1941, Atlanta, Ga.

Semiannual meeting, June 16–20, 1941, Kansas City, Mo.

Association of Iron and Steel Engineers. Annual spring conference, April 28, 1941, Youngstown, Ohio.

Edison Electric Institute. June 2–5, 1941, Buffalo, N. Y.

Electrochemical Society. Spring meeting, April 16–19, 1941, Cleveland, Ohio.

Illuminating Engineering Society. 2d annual lighting conference, April 25–26, 1941, San Francisco, Calif.

National Electrical Manufacturers Association. May 11–15, 1941, Hot Springs, Va.

National Fire Protection Association. Annual meeting, May 12, 1941, Toronto, Ontario, Canada.

Society for the Promotion of Engineering Education. 49th annual meeting, June 23–27, 1941, Ann Arbor, Mich.

Society of Automotive Engineers. National production meeting, scheduled for May 12–13, 1941, Milwaukee, Wis., has been postponed.

Summer meeting, June 1–6, 1941, White Sulphur Springs, W. Va.

Honors • • • •

J. C. Smith Memorial Medal Founded by Engineering Institute of Canada

The Julian C. Smith Memorial Medal has been established to perpetuate the memory of the late Julian C. Smith (A'88, M'99, F'13), past president of the Engineering Institute of Canada and president of the Shawinigan Water and Power Company. Founded by a group of members of the Engineering Institute of Canada, the medal will be awarded annually for achievement in the development of Canada.

Eight Canadians were selected as initial recipients of the medal, presented at the annual meeting of the Institute February 7, 1941. They were:

Sir Herbert Holt, chairman of the board, Royal Bank of Canada; Beaudry Leman, president, Banque Canadienne Nationale; Augustin Frigon (A'20) assistant general manager, Canadian Broadcasting Corporation; R. J. Durley, former professor of mechanical engineering, McGill University; Honorable C. H. Magrath, former chairman,

Canadian section, International Joint Commission; W. D. Black, industrialist, member of executive committee, Bank of Canada; Doctor F. W. Gray, mining engineer, assistant general manager, Dominion Steel and Coal Corporation. A biographical sketch of Mr. Frigon appears on page 181.

1941 Washington Award to Ralph Budd

The Washington Award, conferred annually by a commission representing the Western Society of Engineers, American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Mining and Metallurgical Engineers, and AIEE, has been presented for 1941 to Ralph Budd, president of the Chicago, Burlington, and Quincy Railroad. Bestowed "in recognition of pre-eminent service in advancing human progress," the award was given to Mr. Budd "for vision and courageous leadership in advancing the technological frontiers of high-speed railroad transportation." The John Fritz Medal for 1941 also was awarded to Mr. Budd. In that connection a biographical sketch of him appeared in the December 1940 issue, page 524.

Industry • • • •

Use of Rubber Products in Combating Static Charges

Growing recognition of the importance of the problems created by static charges in such divergent activities as factories, granaries, hospitals, and the oil and aviation industries is reflected in a report on semiconducting rubber and synthetic rubber compounds, prepared by A. E. Juve of the technical department, mechanical division, B. F. Goodrich Company, Akron, Ohio. Highlights of the report follow:

Phenomena associated with the accumulation and discharge of static charges are experienced by everyone. Aside from lightning, the most common experiences are probably the evidences of static charges in combing one's hair, scuffing of the feet on a dry carpet, separating two sheets of paper, and many similar occurrences. These phenomena are usually unobjectionable, though they may be a nuisance and often extremely uncomfortable. In many cases, however, particularly in industry, the discharge of a static accumulation in the presence of inflammable solvents or dust mixtures can be extremely hazardous.

Static charges may be developed in a variety of ways. Primarily, friction between two insulating materials or within an insulating liquid or gas is required. Static charges may also be developed in the absence of friction as when a liquid is broken up into small particles or a mist, or when a mist coalesces into larger particles.

In factories the uncontrolled discharge of static accumulations built up in belts, especially those operating on insulated pulleys, is blamed for an estimated annual fire loss of $3,000,000, according to the National Fire Protection Association.

In aviation the natural flow of air across the body of a plane in flight creates a charge which, if it were not controlled, would reduce the efficiency of de-icing equipment; the same applies to airplane tires.

The turbulent flow of gasoline through hose in loading and delivery operations of the oil industry also creates an obvious danger; while filling stations face a static hazard because automobile bodies become charged in the same way as planes. In this instance the discharge would be particularly hazardous, but for various elementary protective measures adopted widely.

The development of semiconducting rubber and synthetic rubber compounds has been the means of solving a number of important problems involving hazards due to static discharges. Undoubtedly the availability of these materials now will be the means of solving many more.

Some of the applications in which conductive rubber already is being utilized are the following:

(*a*). V-belts for washing machines utilizing a conducting cover which prevents a difference in potential between the motor and the washer from building up.

(*b*). Treads for airplane tires which on landing provide a path for the grounding of the charge accumulated on the plane during flight.

(*c*). Conducting surface on Goodrich de-icer to bleed off to the metal wing structure the static generated during flight, thus preventing a discharge which might puncture the air tubes of the de-icer and reduce its efficiency.

(*d*). Gasoline hose nozzles of conducting synthetic rubber to discharge static existing on cars when they come into the station, as well as the charges generated by the turbulent flow of gasoline.

(*e*). Rubber products, such as mats, heels and soles, sheeting, anesthesia tubing, masks, etc., in hospital operating rooms to eliminate the danger of static discharges igniting anesthetics.

"Two Per Cent for Research." Industrial research is the United States' best insurance against post-war depression, according to a report entitled "Two Per Cent for Research", issued by the National Association of Manufacturers and prepared by Doctor Karl T. Compton (F'31) president of Massachusetts Institute of Technology and chairman of the NAM advisory committee on scientific research. A survey of the research budgets of manufacturing companies showed that two per cent of gross sales income is spent for research by a typical company in a normal year. "If all American industry spent two per cent of gross sales income for research, there could be mobilized in America a quarter of a million scientists and engineers and a billion dollars a year for the development of new goods, new services, new industries, new jobs, and new sources of wages and salaries," Doctor Compton's report declares.

B. M. Tassie Returns to Pacific Coast. A leading executive in the electric appliance industry for the past decade, and closely associated with the industry for a quarter-century, B. M. Tassie has been appointed manager of appliance sales for the newly consolidated Pacific district of the General Electric appliance and merchandise departments, with headquarters in San Francisco. For the past ten years Mr. Tassie has been president of Manning Bowman and Company, electric appliance manufacturers, an organization with which he became affiliated in 1915 as Pacific Coast district manager, with headquarters in San Francisco. Becoming vice-president in 1930, he moved to the company's headquarters in Meriden, Conn., and shortly afterward was elected president. For the past five years he has been a member of the board of governors of the National Electrical Manufacturers Association, and has served on many industries' committees.

Westinghouse to Hire Graduates, Despite Draft. Engineering college seniors interested in working for the Westinghouse Electric and Manufacturing Company will be considered for positions on their merits, regardless of draft numbers or commissions, according to recent announcement. Continuing the policy of interviewing some 2,500 college seniors annually, in co-operation with administrators of accredited colleges, the company expects to select at least 200 of these to enter its employ during the summer and fall. If any of those hired are called up for military training, a deferment plan will be worked out if possible, the company's announcement stated. After a year with the company, the men will be eligible for a year's leave of absence for training, after which they can return to their positions.

Diesel-Electric Freighter for Santa Fe. Following tests of the Diesel-electric freight locomotive completed by Electro-Motive Corporation in 1939, the Santa Fe Railroad ordered a 5,400 horsepower locomotive, which went into regular freight service during February 1940. It consists of two 2,700 horsepower units, each with two 16-cylinder two-cycle engines rated at 1,350 horsepower, and is designed to haul 100 loaded cars on level track at 75 miles per hour, as compared with standard speeds of over 100 miles per hour for passenger Diesel-electrics. Advantages claimed for Diesel-electrics over steam locomotives include fewer service stops, making faster freight schedules possible, and operation during a larger share of time, increasing locomotive miles per year even at identical speeds.

Indiana Transmission Lines. The engineering department of the State of Indiana has prepared a map of the electric transmission lines within the state. Blue line prints of this map, which is 42 by 72 inches in size, may be obtained from The H. Lieber Company, Indianapolis, Ind.; price, $1.25. A limited number of smaller reprints of the map are available for free distribution and may be obtained from the Engineering Department, Public Service Commission, State of Indiana, Indianapolis.

Cashew Varnish. An insulating varnish of the phenolaldehyde type, in which the natural phenol obtained from the outer shells of cashew nuts is used, has been developed by the Irvington Varnish and Insulator Company, *Business Week* reports (March 1, 1941). Since the varnish dries from the inside by heat-induced polymerization, it is adapted especially for the impregnation of large electric coils insulated with asbestos or Fiberglas.

Letters to the Editor • • •

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, ELECTRICAL ENGINEERING reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Total Security—A Challenge

To the Editor:

Do we accept the challenge?

I have read with great interest and pleasure the address, "Total Security—A Challenge", by Charles E. Wilson, president, General Electric Company, published in ELECTRICAL ENGINEERING, March 1941, pages 99–105.

Engineers have pioneered in leading the world to its present heights of technical and mechanical achievement. Through the application of the same vision and determination, they can help to lead the way to "total security".

We, as engineers, must accept this challenge in the same spirit of national service emphasized by Mr. Wilson.

I feel that it is our individual responsibility to mine out the leaders among like-minded men for this new pioneering under Mr. Wilson's leadership. We all can help to mobilize these men in our own Sections. They may be in our plant, office, or community. Everywhere in our ranks are the men whose ideas can produce "total security". It won't happen by chance—it can happen through our individual co-operation.

MURRAY F. SKINKER (F'34)

(Associate director of research, Consolidated Edison Company of New York, Inc., Brooklyn, N. Y.)

(*Editor's Note:* The exchange of ideas through these columns *could* lead to helpful suggestions as to how to develop and implement Mr. Wilson's outlined program of total security.)

A Simple Method of Calculating Power Factor

To the Editor:

The November 1940 issue of ELECTRICAL ENGINEERING contained a very interesting letter by Troy D. Graybeal in which he describes a simple method for the calculation of power factor. The method involves the use of a slide rule having an inverse *C* (or *CI*) scale, in addition to the standard *A*, *B*, *C*, and *D* scales.

Since a great many engineers are still using slide rules having only the four standard scales, the following alternative method for the calculation of power factor is suggested.

Using the form and nomenclature of Mr. Graybeal's letter, Let

P = active power in kilowatts
Q = reactive power in kilovolt-amperes
PF = power factor

METHOD

1. Set Q on the C scale opposite P on the D scale (as before).

2. Note reading on the A scale opposite the index of the B scale. This reading is equal to $(P/Q)^2$. Since P/Q and also its square may be either greater or less than unity, the decimal point must be located carefully (as before).

3. As in the case of the original method, add unity (1.00) to the reading to give the value $1+(P/Q)^2$. Set this value on the B scale opposite the $(P/Q)^2$ reading on the A scale. The resultant reading on the A scale (opposite index of B scale) is equal to $(PF)^2$.

4. Set the indicator to the reading $(PF)^2$ and read the power factor PF at the indicator hairline on the D scale.

THEORY

Since the expression for power factor is:

$$PF = \frac{P}{\sqrt{P^2+Q^2}} = \frac{(P/Q)}{\sqrt{1+(P/Q)^2}}$$

it follows that by squaring both sides of the equation:

$$(PF)^2 = \frac{(P/Q)^2}{1+(P/Q)^2}$$

we obtain an expression equal to the resultant value of step 3.

Then $PF = \sqrt{\frac{(P/Q)^2}{1+(P/Q)^2}}$ = the result obtained in step 4. By way of illustration let us take example 1 of the original method:

$P = 4{,}000$ kw
$Q = 3{,}000$ kva (reactive)

1. Set 3,000 on scale C opposite 4,000 on the D scale.

2. Read 1.78 on scale A opposite the left-hand index of scale B.

3. Unity added to 1.78 is 2.78. Set 2.78 on the B scale opposite 1.78 on the A scale and note the resultant value of 0.64 on the A scale.

4. Set the indicator to the 0.64 reading on the A scale and read $PF = 0.800$ on the D scale.

FRANK SMITH (M'38)

(Equipment engineer, Teleregister Corporation, New York, N. Y.)

The Application of Electricity for the Auxiliaries of Railroad Trains

To the Editor:

With reference to the paper by J. E. Gardner on "The Application of Electricity for the Auxiliaries of Railroad Trains" (*AIEE Trans., Jan. '41, p. 34*) it is interesting to attempt an economical design for power to a long train, say 12 cars. Based on the figure of 45 kw per car quoted in the paper, the total for the train would range between 350 and 500 kw depending on whether or not steam is used for heating. It is desirable from the standpoint of fuel economy to relieve the locomotive from the generation of steam for this auxiliary power, so suggestion is made of a condensing turbogenerator set with extraction of low-pressure steam for car heating and an automatically controlled boiler, all located in a special power car or in a baggage car. The transmission of this power along the train at low voltage would result in feeder cables of 2,000,000 circular mils cross section, which would not be practical in the flexible connections between cars; not to speak of carrying the cables under the car floors. Cable sizes at three phase 60 cycles 550 volts, however, would be entirely feasible with appliances already developed. Five hundred and fifty volts is a standard apparatus voltage. A refinement leading to a small reduction in cable sizes and costs would be to raise the voltage, without increasing the amount of insulation, to 600 volts as permitted by the National Electrical Code or to somewhere between 650 and 700 volts as governed by motor and generator coil wrappings. The machines furnished for train use would be special in mechanical features anyway, so that raising the voltage a little should not add to the cost. At each car there would be a transformer stepping down to 120/208 volts four wire three phase, or, if a storage battery is demanded, to a motor generator set with induction motor and d-c generator. On account of constant speed and 60-cycle frequency, and also because the speed could be high, this unit would be small, light, and relatively inexpensive. The air-conditioning compressor could be driven by a standard motor or possibly by mechanical drive from the motor generator set. All mechanical drives from car axles would be eliminated. Normally power would be supplied from the turbogenerator set ahead but for occasions when it could not be used, as at underground stations where sleeping cars are on the tracks some time before the train leaves, power might be supplied from three-phase 220-volt outlets along the track with portable air-cooled transformer units to step up from 220 to 550 or 650 volts, whatever is used, or the turbogenerator might be provided with a motor fed from the trolley or third rail. A further possibility is to mount a 400- or 500-kw motor-generator set on the electric locomotive which would be used in such places.

Such a system, eliminating generation of auxiliary power by the locomotive and doing away with mechanical drives at the cars, and made up of units of high efficiency, should compare favorably in first cost with the present apparatus, and may be expected to show low fuel and maintenance costs.

SELBY HAAR (A'07, M'13)

(Assistant electrical engineer, Board of Transportation, City of New York, N. Y.)

Matrices in Engineering

To the Editor:

A point of interest regarding the solution of the discriminant matrix for the transient roots of a set of simultaneous differential equations representing a linear network has come to the attention of the writer. It is based on the article by Louis Pipes in September 1937 ELECTRICAL ENGINEERING (AIEE TRANSACTIONS), pages 1177–90. Doctor Pipes points out (page 1188) that one of the roots for the transient solution

of the equations of such a network can be evaluated by a simple matrix transformation as follows: The matrix is represented in the form

$$\omega^2[L]-1/\omega[1/C]=[Z]$$

Doctor Pipes obtains the expression for the transient ω in the form

$$\omega^2[I]-[L]^{-1}[1/C]=0$$

as the equation to be solved. This yields, on application of his root-squaring method as outlined in that paper, the root having the greatest value of ω.

It is equally simple to evaluate the root having the smallest value of ω in an exactly similar manner. In this case, one substitutes for ω the value $1/\mu$. Then we have the equation in the form

$$\mu[1/C]-1/\mu[L]=0$$

Solving for μ, we obtain

$$\mu^2[I]-[1/C]^{-1}[L]=0$$

Then again application of the root-squaring method will yield a second root. In this case, as in the previous case, the ratio of the currents in the various meshes is evaluated in the final matrix resulting from the operation of root-squaring. The root obtained by this operation, as stated, is the smallest root of the matrix.

In the case of a problem involving two meshes only, however, the method simplifies further. If we examine the matrices $[1/C]^{-1}$ and $[L]^{-1}$, we notice that their values are just the original matrices with the rows interchanged and the columns interchanged divided by the value of the determinant of the matrix. Carrying out the operation of solving for ω and μ, we find that the only difference in the values of the two is the fact that ω is divided by the determinant of $[L]$, and μ by the determinant of $[1/C]$. Therefore, the ratio of the two roots can be evaluated. We see from this evaluation that if we know one root, it is very simple to determine the other, merely by multiplying and dividing the values of the determinants by the proper numbers. Evaluation of this also shows that the ratio of the transient currents for the two roots has the same magnitude, but the large current for one root is the small for the other. It is perhaps best to consider an example or so in order to demonstrate the value of this simplification.

Take the matrix

$$[Z]=\begin{pmatrix}(4\omega^3+10^4) & 3\omega^3\\ 3\omega^3 & (3\omega^3+10^4)\end{pmatrix}$$

Here

$$D_L=3$$
$$D_c=1\times10^8$$

Then

$$[\omega^3]=[L]^{-1}\left[\frac{1}{C}\right]=\frac{1}{3}\begin{bmatrix}3 & -3\\ -3 & 4\end{bmatrix}\begin{bmatrix}10^4 & 0\\ 0 & 10^4\end{bmatrix}=\frac{10^4}{3}\begin{bmatrix}3 & -3\\ -3 & 4\end{bmatrix}=[R_0]$$

(by definition)

Multiply R_0 by matrix $\begin{bmatrix}1\\1\end{bmatrix}$

$$[R_1]=[R_0]\begin{bmatrix}1\\1\end{bmatrix}$$

Define

$$[R_j]=[R_0][R_{j-1}]$$

Then, by Pipes' rule,

$$\omega^3=j\xrightarrow{\lim}=\frac{R_j}{R_{j-1}}$$

$$R_{j+1}=\omega^3\cdot K\begin{bmatrix}-0.848\\ 1.000\end{bmatrix}$$

K is product term resulting from $[R_0]^j\begin{bmatrix}1\\1\end{bmatrix}$

In this problem

$$\omega^3=1/3\times6.54\times10^4=2.18\times10^4$$

$$\frac{I_1}{I_2}=\frac{-0.848}{1.000}$$

Solving for μ^2 in like manner,

$$[\mu^2]=\frac{1}{10^8}\begin{bmatrix}3 & 3\\ 3 & 4\end{bmatrix}\begin{bmatrix}10^4 & 0\\ 0 & 10^4\end{bmatrix}$$

Evaluating μ^2,

$$\mu^2=\frac{6.54\times10^4}{10^8}=6.54\times10^{-4}$$

$$\frac{I_1}{I_2}=\frac{1.000}{0.848}$$

Hence, if we write D_c as a, and D_L as b, we have, calling the $6.54\times10^{+4}$ the reduction factor c,

$$\omega^2=c/D_L=c/b$$
$$\mu^2=c/D_c=c/a$$

We must remember here that

$$\mu=1/\omega_0$$

This can easily be shown to be true in general, if one will call

$$[L]=\begin{pmatrix}a & b\\ c & d\end{pmatrix}$$

and

$$[1/C]=\begin{pmatrix}e & f\\ g & h\end{pmatrix}$$

Evaluation of ω and μ from these equations will be found to verify the conclusions stated.

Owing to the fact that the inverse of a matrix of higher than second order does not consist of a simple rearrangement of the original matrix, this does not hold true in general.

KEATS A. PULLEN, JR. (Enrolled Student)

(Graduate school, Johns Hopkins University, Baltimore, Md.)

Books Received •

"Practical Electricity for Home Study." This four-volume set of books, totaling something more than 1,100 pages, is intended, as the name implies, to serve as a home-study text for those of at least high-school level of ability, who desire to attain something of a practical working knowledge of electricity and its more common applications. The material embraced has been used as by the author, Frederick C. Raeth, in his Canadian School of Electricity in Montreal, as the subject matter for both classroom and correspondence courses. The series presents in simple language most of the essential basic principles of electricity, largely in the chronological order in which they were developed, ranging from the voltaic cell to the simpler typical industrial and commercial applications. The manner of presentation is that of a series of graded lessons generously illustrated to facilitate an understanding of the subject matter and supplemented by separate test questions intended for use by the student in progressively testing his understanding. Published by D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York, N. Y.; per set $8.95.

International Electrotechnical Vocabulary, Spanish Edition. Completion of a Spanish version of the six-language electrotechnical vocabulary developed by the International Electrotechnical Commission has been announced by the Argentine Electrotechnical Committee to the American Standards Association. The Spanish edition maintains the idioms and numerical order of the original (*E.E, Jan. '41, p. 54*) but presents the definitions in Spanish instead of in English and French. Translation of the terms alone is given also in German, Italian, French, English, and Esperanto. Copies of the 302-page work may be obtained through the American Standards Association, 29 West 39th Street, New York, N. Y.; price $2.50.

"How America Lives". A study of the living habits of 16 American families, whose incomes range from $100,000 a year to the $26 annual cash income of a sharecropper, has been developed by J. C. Furnas and the staff of the *Ladies' Home Journal*, from actual interviews with the families described. Household equipment, including electric devices, is featured in the studies, along with food, clothing, amusements, and family relationships, and considerable emphasis given to the inadequacy of much American housing in all income brackets. Chosen as one of the typical families were a young engineering graduate and his wife, living on his $33.32 weekly salary as a General Electric testman. Summarizing reports by the editors follow the case studies of individual families, which were published in the monthly issues of the magazine. Published by Henry Holt and Company, New York, N. Y.; price $3.00.

"Vacuum-Tube Voltmeters." This book, by John F. Rider, is intended as a practical exposition of the numerous types of such measuring devices, to serve as a convenient source of information for the engineer, student, and service man. The text covers principles of construction as well as of operation, and presents information drawn from many sources, as well as the author's own compilation of information on the subject. A bibliography of 145 references to articles variously published on vacuum-tube voltmeters and their uses is given. Published by John F. Rider Publisher, Inc., 404 Fourth Avenue, New York, N. Y.; 179 pages; illustrated; price $1.50.

Handbook of Chemistry and Physics. The 24th edition of this standard handbook includes new tables of physical constants of industrial organic compounds and of induced radioactivities, and revision of the table on physical constants of organic compounds, adding about 300 new compounds, and of those on properties of commercial plastics, and on gravimetric factors and their logarithms, in addition to other revision. Contains 2,664 pages; published by the Chemical Rubber Company, Cleveland, Ohio, 1940.

The following new books are among those recently received at the engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries. Information for which is taken from the prefaces of the books in question.

ATM (Archiv für technisches Messen). 103, 104, 105, January, February, March, 1940. R. Oldenbourg, Munich and Berlin. Pages T1–36, F1–2, illustrated, 12 by $8\frac{1}{2}$ inches, paper, 1.50 rm. each. Three numbers of a monthly publication containing classified articles upon various types of apparatus and methods for technical measurements. Certain numbers also contain descriptions of specific instruments manufactured by German companies.

BAUGHMAN'S AVIATION DICTIONARY AND REFERENCE GUIDE, AERO-THESAURUS. By H. E. Baughman. First edition, second printing. Aero Publishers, Inc., Glendale, Calif., 1940. 598 pages, illustrated, $9\frac{1}{2}$ by 6 inches, leather cloth, $5.00. Contains a wide variety of information for those engaged in aviation. Includes a dictionary of aeronautical terms, and the regulations of the Civil Aeronautics Authority which concern students. The information upon occupations, drafting, lofting procedure, shop mechanics, and materials is extensive and practical. Flight maneuvers are illustrated by diagrams. Among other data given are tables of specifications and of needed mathematical data and directories of periodicals, house organs, publishers, clubs, societies, manufacturers, and schools.

AIRCRAFT ENGINES. Volume I. By A. W. Judge. D. Van Nostrand Company, New York, 1940. 380 pages, illustrated, 9 by $5\frac{1}{2}$ inches, cloth, $5.50. Endeavors to present the principles and results of relevant research work upon internal-combustion engines, for the benefit of those entering or already engaged in aircraft engineering work, and also is intended to fill a gap existing in aeronautical literature between the more advanced specialist books on the theory and design and the elementary descriptive ones on aircraft engines, maintenance, etc. Bibliography.

AIRCRAFT DIESELS. By P. H. Wilkinson. Pitman Publishing Corporation, New York and Chicago, 1940. 275 pages, illustrated, $9\frac{1}{2}$ by 6 inches, cloth, $6.00. Outlines the basic principles upon which the Diesel engine functions and the phases and processes involved. Describes fuel-injection equipment, superchargers, and accessories, and the construction of different types of engines. Standardized data are provided in tables. Discusses also the development and mass production of Diesels in Germany and their commercial utility.

INTRODUCTION TO ABSTRACT ALGEBRA. By C. C. MacDuffee. John Wiley and Sons, New York, 1940. 303 pages, diagrams, etc., 9 by 6 inches, cloth, $4.00. Planned for a year's course, the problems furnishing laboratory material and concrete instances of the abstract concepts. The subject is developed logically from the system of rational integers to linear associative algebras. The selected body of facts in number theory, group theory, and formal algebra is offered, to provide a background for the generalized facts of abstract algebra.

RADIO AMATEUR'S HANDBOOK, 18th edition, 1941. American Radio Relay League, West Hartford, Conn. 552 pages, illustrated, 10 by $6\frac{1}{2}$ inches, paper, $1.00, buckram, $2.50. Covers comprehensively the amateur short-wave field. The fundamental principles and the design, construction and operation of transmitting and receiving apparatus are described in detail, including ultrahigh frequency, emergency and portable equipment. Many new illustrations and descriptions of new equipment have been added, and the catalog and manufacturers data section has been expanded.

TIME AND MOTION STUDY AND FORMULAS FOR WAGE INCENTIVES. By S. M. Lowry, H. B. Maynard, and G. J. Stegemerten. Third edition, McGraw-Hill Book Company, New York and London, 1940. 432 pages, illustrated, $9\frac{1}{2}$ by 6 inches, cloth, $5.00. This textbook presents the principles and methods of making time and motion studies and constructing time formulas, as a guide for the factory executive. The organization and supervision of time-study, formula, and wage-payment work are outlined. The present edition has been revised to place greater emphasis on methods-study and leveling procedure.

MAGNETISM AND VERY LOW TEMPERATURES. By H. B. G. Casimir. University Press, Cambridge, England; Macmillan Company, New York, 1940. 93 pages, charts, tables, $8\frac{1}{2}$ by $5\frac{1}{2}$ inches, paper, $1.40. An account presented originally in lectures, of the field of research dealing with the relation between magnetism and very low temperature states. Special attention is given to paramagnetism and adiabatic demagnetization. List of references.

MATERIALS HANDBOOK. By G. S. Brady. Fourth edition. McGraw-Hill Book Company, New York and London, 1940. 591 pages, charts, tables, $9\frac{1}{2}$ by 6 inches, leather cloth, $5.00. The many materials used in industry are identified and described. Information is given on physical and chemical properties, constitution, and uses. Ranges from basic raw materials such as mineral ores and woods to such products as alloy steels and synthetic resins. Intended primarily for purchasing agents and industrial executives, its field is much wider for reference use. Tables are appended.

MECHANICAL VIBRATIONS. By J. P. Den Hartog. Second edition. McGraw-Hill Book Company, New York and London, 1940. 448 pages, diagrams, etc., $9\frac{1}{2}$ by 6 inches, cloth, $5.00. Includes the theory and practical applications to water wheels, steam turbines, automobiles, airplanes, Diesel engines, and electrical machinery. Revised in accordance with recent developments, many new problems added, and list of formulas appended. Bibliography.

PUBLIC UTILITIES AND THE NATIONAL POWER POLICIES. By J. C. Bonbright. Columbia University Press, New York, 1940. 500 pages, 9 by $5\frac{1}{2}$ inches, cloth, $1.25. Discusses control of public utilities, rate regulation, holding companies, and other aspects of Federal policies, and their relation to the question of public ownership. Suggestions for further reading are given.

SALES ENGINEERING. By B. Lester. John Wiley and Sons, New York, 1940. 300 pages, diagrams, 9 by $5\frac{1}{2}$ inches, cloth, $2.00. Defining sales engineering as the art of selling equipment and services that require engineering skill in their selection, application, and use, the author discusses its field, the work of the sales engineer under current conditions, and his training and development.

STATISTICAL PROCEDURES AND THEIR MATHEMATICAL BASES. By C. C. Peters and W. R. Van Voorhis. McGraw-Hill Book Company, New York, 1940. 516 pages, diagrams, etc., $9\frac{1}{2}$ by 6 inches, cloth, $4.50. Designed to bridge the gap between elementary courses and the original monographic contributions which are often highly mathematical. The authors bring together and synthesize the classical statistics and certain new developments, explaining mathematical derivations and their use for students with little mathematical training. Exercises and references accompany each chapter.

STEAM-TURBINE PRINCIPLES AND PRACTICE. By T. Croft, revised by S. A. Tucker. Second edition. McGraw-Hill Book Company, New York, 1940. 298 pages, illustrated, $8\frac{1}{2}$ by $5\frac{1}{2}$ inches, cloth, $3.00. Gives the operating engineer, the plant superintendent, and the manager information necessary for the successful and economical selection and operation of steam turbines. Covers installation, lubrication, testing, and maintenance, with special attention to the economics of steam-turbine operation. Revised to conform to current practice, with a new chapter describing the engineering principles involved in turbine selection and heat balance.

TECHNICAL EXPOSITION. By L. M. Oliver. McGraw-Hill Book Company, New York, 1940. 193 pages, charts, $8\frac{1}{2}$ by $5\frac{1}{2}$ inches, cloth, $1.50. An advanced English text for engineers, presents a series of basic expository problems, with assignments for students, and a full discussion of theory and practice in preparing research papers and reports. Includes also business letter writing, vocabulary, and punctuation.

FESSENDEN, BUILDER OF TOMORROWS. By H. M. Fessenden. Coward-McCann, Inc., New York, 1940. 362 pages, illustrated, 9 by 6 inches, cloth, $3.00. The life and work of one of the American pioneers in radio communication are described by his wife. His other technical achievements include submarine signalling and detection, the generation and storage of power, and many articles on mathematical, physical, and electrical subjects. He also carried on research on the predeluge civilizations. Bibliography.

THE DEVELOPMENT OF MATHEMATICS. By E. T. Bell. McGraw-Hill Book Company, New York and London, 1940. 583 pages, $9\frac{1}{2}$ by 6 inches, cloth, $4.50. An account of the part played by mathematics in the evolution of civilization, describing the main principles, methods, and theories of mathematics that have survived, from about 4000 B.C. to 1940 A.D. Besides outlining the development of the leading ideas, the author explains the mathematics involved. Antiquarian interest is subordinated to exposition of things still alive in mathematics.

GRAPHS, HOW TO MAKE AND USE THEM. By A. Arkin and R. R. Colton. Revised edition. Harper and Brothers, New York and London, 1940. 236 pages, illustrated, $9\frac{1}{2}$ by 6 inches, cloth, $3.00. An introductory work which explains all the usual methods of graphic representation, outlining general principles and proper equipment for graph construction, and a wide variety of uses in business, economics, engineering, and other fields.

TORCH OF CIVILIZATION. The Story of Man's Conquest of Darkness. By M. Luckiesh. G. P. Putnam's Sons, New York, 1940. 269 pages, illustrated, $8\frac{1}{2}$ by $5\frac{1}{2}$ inches, cloth, $3.00. Following a discussion of the history of artificial light and its influence on developing civilization, the author describes in detail modern light sources. Separate chapters are devoted to gas flames and mantles, electric arcs, glowing filaments, luminous vapors, and fluorescent sources. The relations of light with sight, art, life, and health are also discussed.

STORAGE BATTERIES. By G. W. Vinal. Third edition. John Wiley and Sons, New York, 1940. 464 pages, illustrated, 9 by 6 inches, cloth, $5.00. Standard textbook and authority on batteries, charging methods and equipment, care of batteries, and remedies for troubles encountered. The physical and chemical properties of storage battery materials are discussed, and manufacturing methods are described. Chapter on present-day uses for storage batteries. Revised.

THOMAS' REGISTER OF AMERICAN MANUFACTURERS. 31st edition, December 1940. Thomas Publishing Company, New York, Boston, Philadelphia, San Francisco, Toronto, Canada, 1941. 5,000 pages, illustrated, $14\frac{1}{2}$ by 9 inches, cloth, $10.00 to former subscribers, $15.00 to new subscribers. This huge annual directory of American manufacturers has its customary three main sections: the classified directory of products (with index) in which firms are listed, with capital ratings, geographically under each product; the alphabetical list of manufacturers, giving addresses, subsidiaries, branches, etc.; and the trade name index. The innovation, introduced in the previous edition, of assigning arbitrary numbers to advertisers, including a "key" index, has been expanded in the present volume.

TRENDS IN INDUSTRIAL PENSIONS (Industrial Relations Monograph Number 5). By M. W. Latimer and K. Tufel. Industrial Relations Counselors, New York, 1940. 88 pages, tables, $9\frac{1}{2}$ by 6 inches, paper, $1.00. The objectives of this monograph, which analyses some 350 active company pension plans, are: first, to determine whether the characteristics and trends of pension systems have changed in the last seven years, and, if so, in what direction; second, to analyze the growth or decline and the present extent of the voluntary pension movement; and third, to consider the adaptation of private pension systems to governmental old-age insurance legislation. The numerical findings of the investigation appear in a group of tables.

WELDING METALLURGY. Volumes I and II. By O. H. Henry and G. E. Claussen. American Welding Society, New York, 1940. 359 pages, illustrated, 8 by 5 inches, cloth, $1.50. Intended to familiarize members of the welding industries, including fabricators and designers, with the metallurgical aspects of the welding process, this book deals with the structure, properties, and composition of welded materials. It shows how the steel is affected by the heat conditions of heat and stress, explains heat-treatment procedure and points out the way in which metallurgy can be used to control the welding process.

ATM (Archiv für technisches Messen) 111, 112, 113, September, October, November 1940. R. Oldenbourg, Munich and Berlin, pages T97–119, F3–5, illustrated, 12 by $8\frac{1}{2}$ inches, paper, 1.50 rm. each. Three numbers of a monthly publication containing classified articles upon various types of apparatus and methods for technical measurements. Certain numbers also contain descriptions of specific instruments manufactured by German companies.

APPLIED CHEMISTRY FOR ENGINEERS. By E. S. Gyngell. Edward Arnold and Company, London; Longmans, Green and Company, New York, 1940. 328 pages, illustrated, 9 by $5\frac{1}{2}$ inches, cloth, $4.00. Deals with the chemistry of materials and processes used by the engineer. Major topics discussed are fuels and combustion, metallic corrosion, paints and varnishes, water treatment and sewage disposal, cements, and lubrication. Selected bibliographies.

HOISTING MACHINERY. By W. H. Atherton. Technical Press, London, 1940. 314 pages, illustrated, 10 by 6 inches, cloth, 32s 6d. Deals with the design, construction, maintenance, and uses of the types of material-handling equipment that perform intermittent short-range movements: cranes, derricks, grabs, skip hoists, stackers, telphers, and transporters. Literature references in text and in a brief bibliography.

Transactions Section

Preprint of Corresponding Pages From the Current Annual Transactions Volume

Any discussion of these papers will appear in the June 1941 "Supplement to Electrical Engineering—Transactions Section"

The Service Factor Rating of Arc-Welding Generators and Transformers

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Synopsis: The primary purpose of rating an electrical machine is to give the user an idea of what he may expect from the unit which he purchases.

It is the purpose of this paper to propose a method of rating arc-welding generators and transformers which will give a truer picture of their working ability than is afforded by the present one-hour rating. Such a method of rating will be beneficial both to the customer who buys and uses arc welders and to the manufacturers who produce and market the units. The user will be better able to select a machine which will do the job to be performed, and at the same time he will be assured that he is not purchasing a machine unduly large for his requirements.

The present custom is to give welding transformers and generators a one-hour rating, specifying the current they can deliver for a one-hour period, starting cold, without exceeding the permissible temperature rise. The plan here proposed is to give them a current rating indicative of their normal operating capacity, or short-time welding ability; and an additional service factor rating, indicative of their continuous current capacity, as limited by thermal considerations.

All electric apparatus has these two major limitations on its output, one a "size" limit expressed by breakdown torque, commutation limit, or voltage drop; and the other a thermal limit expressed by the degrees temperature rise permissible for the type of insulation used. These two limits are usually quite independent of each other, so that no single number, such as a one-hour rating, can fully describe the usability of the apparatus. The proposed service factor rating gives both of these limits, and therefore gives the user the data for applying the apparatus to a variety of duty cycles.

In conclusion, it is suggested that welding generators and transformers be designed for a service-factor rating of 75 per cent, since this corresponds best to typical welding duty cycles. It is also proposed that the standard AIEE values of temperature rise by resistance for continuous rated machines, 60 degrees centigrade for class *A*, or 80 degrees centigrade for class *B* insulation, be recognized as the limiting values in continuous operation at the service-factor rating.

Paper 41-33, recommended by the AIEE committee on standards and presented at the AIEE winter convention, Philadelphia, Pa., January 27-31, 1941. Manuscript submitted November 22, 1940; made available for preprinting December 7, 1940.

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1. For all numbered references, see list at end of paper.

Rating for Welding Service

BEFORE proposing a method of rating, it is advisable to consider the purpose of rating. "The rating of a machine or other equipment is a set of performance characteristics which are subject to verification by test under specified conditions and which by mutual agreement between buyer and seller may serve as a basis of specifications and contracts covering the purchase and sale of the machine or other equipment. The rating is used by the manufacturer in the design and fabrication of the equipment and is used by the purchaser as the basis for application; therefore, the terms in which the rating is stated should be definite, easily verified, of such a nature as to permit intelligent use of the equipment, and as far as possible inclusive of usual conditions as found in practice."[1]

A common sense approach to the problem requires consideration of three different factors:

1. A rating suited to typical welding duty cycles, indicating electrical and thermal limitations.
2. A method of temperature measurement that will give the best indication of actual insulation temperature.
3. Selection of temperature-rise limits to assure satisfactory life of the machine as well as effective use of material in its construction.

In general, there are two types of duty to which an arc-welding generator or transformer may be subjected: Hand welding duty, and automatic welding duty. Because of the infinite variety of hand welding jobs, the duty cycle of such work varies from below 25 per cent up to as high as 75 per cent or 80 per cent of the total elapsed time in the case of production line work. In the case of intermittent welding done in automatic installations, the duty cycles may equal those in the upper brackets of hand welding operation. In a small percentage of cases such as pipe welding and other long seam welding, the length of the arc time may be so long that the application requires a continuous rated machine.

Standards[1] for rating arc-welding transformers and generators now specify temperature rise to be measured by operating the machine at rated current continuously for one hour (one-half hour for the smaller sizes), starting cold. There is also included a statement that transformers should be capable of carrying 75 per cent of rated current continuously. The emphasis has been placed on the one-hour rating and most purchasers, even those having strict specifications of their own, have paid little attention to the continuous capacity, but have required test only at the one-hour rating.

Disadvantages of a Short-Time Rating

In order to illustrate clearly the shortcomings of a short-time rating for machines which must carry cyclic loads, we have borrowed two hydraulic analogy diagrams from L. E. Hildebrand's paper on "Duty Cycles and Motor Rating."[2]

Figures 1 and 2 present hydraulic analogies of temperature rises in two electrical machines. Water flowing into the tank represents motor losses—the smaller stream represents no load losses and the larger stream stands for additional losses under load. The height of water in the tank is analogous to temperature rise, while the capacity of the tank is analogous to the heat storage capacity of the machine. The outlets at the bottom of the tank illustrate heat dissipation.

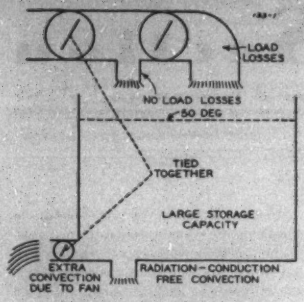

Figure 1. Hydraulic analogy

Short-time rated machines
Poorly ventilated

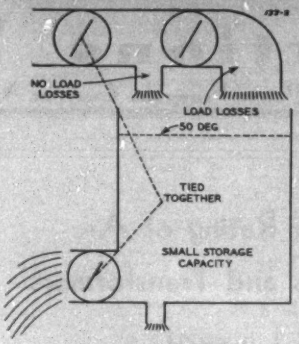

Figure 2. Hydraulic analogy

Short-time rated machines
Well ventilated

In these two diagrams the losses in the two machines are the same. However, in the machine shown in figure 1 we find that the heat dissipating ability as illustrated by the size of the outlet is small, while the thermal capacity of the machine as indicated by the volume of the tank is large; so that in the period of one hour the level of the temperature will just reach a point of 50 degrees rise.

In the case of the diagram in figure 2, we find a machine with a much smaller thermal capacity which is illustrated as a smaller tank. It is only as a result of the large heat dissipating ability as illustrated by the large outlet pipe that this machine is able to run for a period of one hour without exceeding the temperature rise of 50 degrees. Thus, here we have two machines both of which will meet identically the same one-hour load rating specification. But if we were to hold these two machines on a duty-cycle basis all day, we would find a great difference in their operation. The machine represented by the diagram in figure 1 has small heat dissipating ability; therefore, during periods of no load, heat is dissipated from this machine very slowly. During a day's welding, we find that the level of temperature rise continues to climb and may far exceed that obtained on the constant load during the one-hour period.

On the other hand, as soon as the load is removed from the machine represented by the diagram in figure 2, we find that heat is drained rapidly from that machine as a result of the high heat dissipating ability of that unit. With heat being thus quickly and efficiently removed, this unit can run all day on a duty-cycle load and will likely not even reach the level of temperature rise indicated at the end of a one-hour period.

Figure 3 illustrates these points in terms of specific transformer designs. In the figure, curve B_1 is the heating curve of a transformer with a one-hour rating. This same transformer carrying welding load will heat as in curve B_3, if designed with adequate cooling.

However, a transformer could be built with insufficient cooling which would match the one-hour heating curve B_1 but would heat under welding load as in curve B_3. Such a transformer would run considerably over its rated temperature rise on a long-continued load, such as a half a day's work. A transformer designed with heavy copper coils at low current density without adequate ventilating ducts, or a transformer with windings wound close on the core to allow coil heat to be absorbed by the slowly heating core, would meet the one-hour temperature rise but would run hot on actual welding service.

On the other hand, a transformer can be built with heating curves similar to A_1 and A_3. This transformer would reach rated temperature rise in only one-half hour on the short-time test at continuous rated current (curve A_1), but would operate well under rated temperature rise on all-day welding duty as shown by curve A_3. Also, its quick cooling after removal of load (end of curve), would compensate for its quicker heating time by reducing the total time at high temperature.

It can thus be seen that a properly designed transformer rated for a half-hour short-time test may be better than a poorly designed unit which meets the one-hour test. This is the most important reason why a short-time rating may be meaningless. The short-time rating is artificial, does not take into account the important consideration of all-day operation, and does not tell the operator what he can obtain in actual service without injury to the transformer.

Another drawback to the short-time rating is the difficulty of obtaining accurate tests. The problems involved in starting cold, adjusting load accurately and quickly, and timing accurately are serious and make the tested temperature rise obtained doubtful, especially if thermometers are used.

Continuous Ratings

One alternative method of rating is to rate the welding generator or transformer in terms of its maximum continuous current obtainable without exceeding rated temperature rise. This is done to a considerable extent in Europe. Continuous rating suffers from the disadvantage that it does not tell the operator what current he can obtain while welding—always more than the continuous current—since all welding operations are inherently discontinuous loads.

Typical Duty Cycles

In manual welding there is no such thing as a continuous load. In hand welding the maximum time on without interruption is short, about two minutes, the time for one stick of electrode to be consumed. After one electrode is consumed the operator must raise his hood, remove the end of the consumed electrode, insert the new electrode, position the electrode, lower the hood, and restart the arc. This operation consumes time at least equal to ten per cent of the arc time. However, there are always other operations required, such as change or reposition work, chip slag, add parts, change current, rest and delay.

From a careful study of many types of hand welding operations, the writers have come to the following conclusions:

Many welding duty cycles average about 25 per cent.

On highly repetitive work the duty cycle may rise to about 50 per cent. One such cycle is shown in table I in this paper, and is followed by a similar but simplified cycle, table II, which was used as the basis of a heating test. The curve of temperature rise on this test is shown in figure 4. This particular test was made on a large fan-cooled welding transformer.

Exceptional welding jobs have been found with as high as 72 per cent duty. One such is shown in table III. This shows a time study of a job requiring 63 minutes total. However, there was permitted the welding operator an additional 15 per cent time for rest and delay not shown in the table

which would reduce the duty considerably. It seems probable that 70 per cent approaches the maximum duty cycle which can be obtained in long-continued manual welding.

Other Factors Affecting Heating

Since most arc-welding transformers and generators are furnished in standard ratings and are not built to the exact rating needed for a particular job, the factors of overload and underload should also be considered. The overload range of arc-welding transformers is not very large, generally about 25 per cent. Further overload is prevented by the limit of reactance or other type of current control. Here again proper information on the duty-cycle curve in the hands of the operator would be of value, permitting him to keep within safe temperatures by controlling the duty cycle on those jobs where the overload range is used.

It can safely be expected that in the vast majority of applications the machine will be operated at less than rated current. The range of current obtainable at welding voltages generally goes down to 20 per cent of the rated current in order that one machine may be capable of doing a wide variety of work. In many jobs it is necessary to change current several times to accommodate the different sizes of electrodes required to weld an assembly. However, it is necessary to rate the generator or transformer on a reasonably high duty cycle at its rated current for the rating implies that the equipment may

Table I. Typical Heavy Duty Cycles—Hand Arc Welding

Minutes on	Minutes off
	1.93
1.85	0.49
1.85	0.49
1.85	0.60
1.17	3.33
2.16	0.49
0.61	1.68
0.26	0.35
Total 9.75	9.36
Duty cycle 51%	

Table II. Typical Heavy Duty Cycles—Hand Welding

Minutes on	Minutes off
	2
2	0.5
2	0.5
2	0.5
1	3.5
2.5	0.5
0.5	1.5
0.75	1.25
Total 10.75	10.25
Duty cycle 51%	

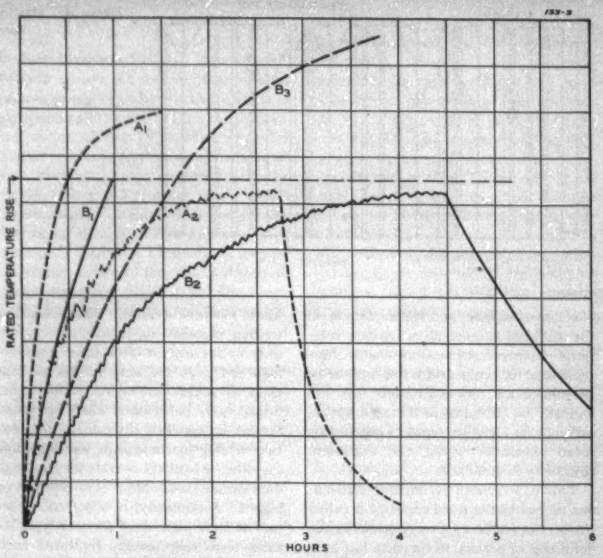

Figure 3. Heating curve

Arc-welding transformer
A—Transformer with low heat storage (half-hour rated)
A_1—Continuous at rated current
A_2—At 60 per cent welding duty cycle
B—Transformer with high heat storage (one-hour rated)
B_1—Continuous at rated current
B_2—At 60 per cent duty cycle (well ventilated)
B_3—Average at 60 per cent duty cycle (poorly ventilated)

be used for the vast majority of welding operations at that current. Nor is it fair to make the standard duty cycle so low as to deprive the user of any increased life he may obtain when using the machine at less than rated current.

Suggested Duty-Cycle Standard

When all the above factors are taken into consideration, the authors feel that a standard duty cycle for rating arc-welding generators and transformers should be 60 per cent. A machine thus rated would carry the vast majority of hand welding operations without exceeding rated temperature. Also, since most welding operations do not exceed 50 per cent time on, a reasonable margin is left for operation at some overload. A maximum time on of six minutes out of ten would insure adequate heat storage capacity.

There is precedent for a duty-cycle rating in welding. All resistance-welding transformers are now rated on a duty-cycle basis, the standard being 50 per cent.

The most comparable test would be of course, a duty-cycle test with the generator or transformer continuously excited and alternately loaded for six minutes and open-circuited for four minutes. This test would result in a saw-tooth shaped temperature curve. Such a test is rather difficult to make due to the problem of accurate timing, but it is provided for in the VDE (German) motor standards. Special arrangements might have to be made to test welders where output current is controlled by taps, rather than by adjustable magnetic means, in order to make sure that each winding is properly heated.

Service-Factor Rating

On the assumption that the temperature rise varies as the square of the load current, a duty cycle with 60 per cent time on would give the same heating as a test with $\sqrt{0.60}=0.775$ current continuously. For the sake of simplicity, therefore, it is suggested that the standard temperature-rise test should consist of a continuous heat run at 75 per cent of rated current, carried on until the temperature rise becomes constant. This test will definitely fix the capacity of the machine on a 100 per cent duty cycle, or

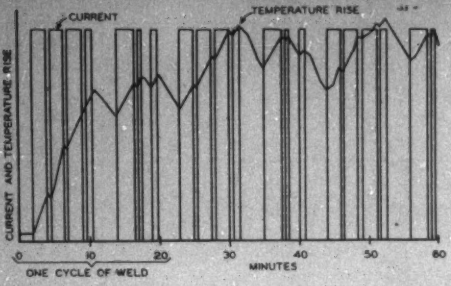

Figure 4. Heating curve

Arc-welding transformer

(51 per cent welding duty cycle)

continuous service, and it also avoids all the difficulties inherent in making transient temperature measurements. Furthermore, the temperature-rise limit to be prescribed for this continuous test will logically be the same as dictated by experience for all other types of continuous rated apparatus, giving the maximum simplicity in standards.

This 0.75 ratio of permissible continuous output to the rated capacity is called the service factor, as it corresponds to the definition of service factor that has long been used for general-purpose motors. Such motors have 40-degrees-centigrade rise at their rating, and a service factor of 1.15, corresponding on the average to the increased load at the 50-degrees-centigrade rise value permissible for continuous rated apparatus in specific applications.[3]

It has already been suggested by L. E. Hildebrand that service factor ratings of less than unity should be used for high torque motors on intermittent duty cycles, instead of the customary short-time ratings.[3] The same reasoning outlined in the preceding paragraphs applies to a wide variety of apparatus in intermittent use. In each case the nameplate rating should be indicative of the safe allowable load for a particular kind of duty, and the service factor indicates the permissible continuous, or rms, load.

On the several grounds of convenience, testing accuracy, and versatility of application, therefore, the service-factor rating method is suggested as preferable for welding transformers and generators; and the specific value of 75 per cent service factor is suggested as most suitable for usual arc-welding service.

Automatic Welding

All the foregoing discussion refers to hand welding, that is, welding with the electrode holder in a man's hand. No attempt will be made in this paper to recommend duty-cycle ratings for automatic machine welding. Many machine welding installations operate at very low duty cycles since it often takes longer to load and align the work in the machine than to make the weld. Many other installations, particularly where one transformer is switched alternately between two welding machines, one welding while the other is loading, operate at very high duty cycles, on the order of 80 per cent or higher. Fortunately, it is not so important to have a standard for such installations since they usually represent such large investments as to justify individual study and application.

Temperature-Rise Measurement

The aim of temperature-rise measurement is to determine the hottest temperature reached by the insulation, in order that long life of the machine may be assured.

The three general methods of temperature measurement are: The measurement of the temperatures upon external parts of windings or core by thermometer or thermocouple, measurement from the cold to hot resistance change of a winding, or the use of embedded detectors.

As a result of the demands of the industry for easily portable arc-welding sets, the trend of generator designs is to small machines which are very well ventilated. The fact that these units are so well ventilated by an air blast means that there is, of necessity, a greater thermal gradient from the inside of the coil winding to the external surface of the insulation. This means that surface temperatures vary widely from internal temperatures and that the extent of this variation is influenced considerably by the method of ventilation employed.

It is very difficult to get accurate transformer temperatures by thermometer or thermocouple unless thermocouples are actually built into the winding. In most natural draft transformers, particularly those with heavy coils, a thermometer or thermocouple on the outside of the coil may read 20 to 30 per cent lower than the average temperature rise of the winding. The rise by resistance method, of course, becomes mandatory in oil or synthetic fluid-immersed transformers since it is then practically impossible to insert thermometers or thermocouples.

While the embedded detector method is of unquestioned desirability in heat flow tests, its use in commercial testing is pretty much out of the question.

A combination of the inadequacy of surface temperature measurements with the difficulty of making embedded detector measurements leads us to the measurement of temperature rise by the resistance method. By the resistance method, it is possible to obtain a true average winding temperature regardless of whether the coil is exposed to a blast of cooling air or whether it is well wrapped up in electrical and thermal insulating material. Although this method will, of course, not give an actual hot-spot temperature indication, yet it will be a much more reliable indication of the hot-spot temperature than any surface temperature measurement.[4]

As an aid in attaining a true indication of temperature rise, we will find that the adoption of the duty-cycle or service-factor method of rating is of considerable help. With short-time periods of test the rate of rise of internal temperatures may be so great that measurements of a final surface temperature are likely to be very inconsistent and consequently therefore, also inaccurate. While it is a fact that a true sportsman will not shoot at a standing bird, fortunately there is no sporting or ethical principle which requires the builders of arc-welding equipment to attempt to measure temperature rise "on the wing." With the adoption of the service-factor method of rating welders it will be possible to allow the temperature of the machine to reach a state of equilibrium and thus allow accurate measurement. The combination of service-factor rating with temperature rise by resistance measurement will assure us that we do not have our heads in the sand but that we will actually know the average temperature rise of the windings in our arc-welding machines. To know the true values of temperature rise is of unquestioned advantage for both the user and the manufacturer of welding machines. The manufacturer can know that he is making optimum use of all of the material within the machine without exceeding safe temperature limits; while the purchaser will be assured of long life machines giving trouble-free operation.

Limiting Temperature Rise

The two important factors governing the life of insulation are maximum temperature and the length of time the insulation is hot.

The maximum permissible operating temperature of the insulation is a function of the type of insulation, both fibrous materials and impregnating compounds. The general subject of insulation characteristics is too long to discuss here, so for the purpose of this paper it will be assumed that the commonly accepted standards[4] will insure satisfactory life of insulation, and that these rises should not be exceeded except for very short intervals of time.

For a given temperature, the life of insulation is reduced more or less directly with time; that is, if a transformer were hot only one-fifth of the time, its insulation could be expected to last five times as long as one hot continuously. For class *A* insulation it has been shown[5] that within limits the life of insulation is reduced roughly 50 per cent for each 8- to 12-degree increase in temperature. Therefore, the life reduction, in aging units, can be approximately estimated in the form of an exponential function of temperature, multiplied by the length of time the temperature persists in the insulation. For class *B* insulation, such as is used in most arc-welding transformers, the rate of aging has not yet been determined; however, it undoubtedly follows some similar law but probably with a higher temperature increment for a given aging.[6]

From the foregoing factors it will be seen that the shapes of the heating and cooling curves of a welder affect insulation life. For example, a welder which heats slowly may have the advantage of slow heating offset by cooling more slowly and thereby keeping its insulation hot longer than a welder which heats and cools quickly.

Since the present NEMA standards for welding generators require measurement of temperature rise by thermometer, it is pertinent to inquire what the corresponding values of rise by resistance are for actual machines now in use. As pointed out previously, and recognized in the AIEE "General Principles Upon Which Temperature Limits Are Based in the Rating of Electrical Machinery and Apparatus," there is a considerably greater difference between the two methods of measurement for highly rated direct-current machines than the ten-degree-centigrade value usually assumed for class *A* insulation. With the forced draft ventilation commonly in use on arc-welder sets, the thermal gradient between the inside windings and the outside of the coils is so great that the actual excess of the rise by resistance over that by thermometer is often 20 degrees centigrade or more.

Depending upon the thickness of insulation over the windings and the intensity of the blast of ventilating air, it is a matter of test record that temperatures measured by the resistance method range from 17 to 42 degrees higher than the values read by thermometer or thermocouple at the outer surface of the coils.

In view of the intermittent character of hand welding, and the satisfactory service records of welders having these relatively high internal temperatures under rated load conditions, it is permissible to set considerably higher limits for temperature rise for short-time rated than for continuous-rated machines. For example, the latest NEMA welding standards[1] permit 100-degrees-centigrade rise by thermometer, or 125 degrees centigrade by resistance, for "class *BB*" insulated welders rated on a half-hour or one-hour basis. Presumably this insulation is similar to the special class *B* insulation used in railway motors, for which 120-degrees-centigrade rise by resistance is permitted.[7] However, as previously indicated, the typical welding duty cycle of 60 per cent time on and 40 per cent time off with a time cycle of only a few minutes, results in no greater operating temperature than would be caused by a continuous load of about 75 per cent of the short-time rated amperes. And, to assure the service life normally expected of electrical apparatus, this average operating temperature should not exceed the standard limiting values for continuous-rated machines, which are: For class *A* insulation, 50 degrees centigrade by thermometer or 60 degrees centigrade by resistance, and for class *B* insulation, 70 degrees centigrade by thermometer or 80 degrees centigrade by resistance.[13] Thus, the 75 per cent service-factor rating method with the standard continuous-temperature limits is a logical outcome of the recent trends in welding transformers and generators.

Table III. Typical Heavy Duty Cycles—Hand Welding

Minutes on	Minutes off	Minutes on	Minutes off	Minutes on	Minutes off
	2.07	1.24	1.72	0.66	2.92
1.54	0.19	0.90	0.19	2.70	0.19
1.54	0.19	0.90	0.19	0.34	0.19
1.54	0.19	0.90	0.19	0.34	0.19
1.54	0.19	0.90	1.32	0.34	0.19
1.54	0.19	0.90	0.19	0.34	0.19
1.54	0.19	0.90	0.19	0.34	0.19
1.54	0.19	0.90	0.19	0.34	0.19
1.54	0.19	0.90	0.19	0.34	0.19
1.54	0.19	0.90	0.19	0.34	0.60
1.54	0.19	1.24	0.85	2.37	0.44
1.54	0.19	0.66	0.19	2.37	0.18
1.54	0.70	0.66	0.19		
1.24	0.19	0.66	0.19		
Total				45.88	17.26
Duty cycle					72.7%

Conclusions

After consideration of all these factors, it is recommended that welding generators and transformers be given a nameplate rating representative of their expected normal welding currents, as at present, and in addition a service-factor rating of 75 per cent. Acceptance tests would then include a continuous test run at 0.75 of the nameplate amperes without exceeding a limiting temperature rise by resistance of 60 degrees centigrade for class *A* insulation or 80 degrees centigrade for class *B* insulation; or corresponding values of 50-degrees-centigrade and 70-degrees-centigrade rise if the thermometer method of measurement is used.

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Engineering Requirements for Program Transmission Circuits

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Synopsis: Present-day program networks are reviewed from the standpoints of engineering, design, and operation as developed to meet the needs of the broadcasters. The factors requiring consideration in the further development of program networks in anticipation of future needs are also discussed. The presentation of the paper is supplemented by a demonstration of the quality obtainable by transmission over various types of telephone facilities.

Introduction

THE growth of radiobroadcasting to the magnitude of a major national industry within the last 20 years has been accompanied by the development of a nation-wide system of wire-line networks interconnecting hundreds of broadcasting stations. Papers have been presented before this Institute from time to time[1,2,3] describing the types of plant used for these networks and discussing important features of their design and operation. With these 20 years of experience as a background, it should now be of interest to review how the various requirements of broadcasting have influenced the development of the networks and to consider some of the factors which have determined the point to which transmission and operating features have so far been carried.

Simply stated, broadcasting is a means by which sounds originated at one place are reproduced simultaneously to large numbers of listeners distributed over wide areas. The simplest possible radiobroadcasting system would consist of a microphone, a radiobroadcast transmitter and some radio receiving sets. Such a system could serve only the listeners within the comparatively limited service area of the transmitter. To serve the whole nation many transmitters must be established about the country. Furthermore the most desirable sources of program are not usually in the neighborhood of the transmitter to which a particular listener can tune, since talent tends to be concentrated in certain parts of the country, and special events of interest may occur anywhere. To give a true country-wide service so that every listener can hear the programs he enjoys wherever they may originate, a supplementary transmission system must be provided, interconnecting the many studios and broadcasting stations. The wire networks that perform this function comprise the subject matter of this paper.

The present extent of the wire-line facilities which are associated with the major portion of these networks is indicated in figure 1. The width of the lines on this chart has been made proportional to the numbers of circuits in the various sections. The total length of these circuits is in excess of 110,000 miles, and it is not unusual for a program originating at some point on a network to traverse more than 7,000 miles of circuit before being broadcast by the most remote station.

The requirements which the program networks must meet are in the final analysis determined largely by the needs of the broadcasters. The objective of a program network service is to meet these needs in as complete and prompt a manner as possible consistent with reasonable cost. With this objective in mind, it is necessary in planning the plant to consider not only the day-to-day needs, but the possible future needs as well. The importance of this may be appreciated when it is considered that plant provided today for program transmission service will need to be adaptable to the service requirements 10 or 20 years hence. As a result of such planning, cables and equipment installed 5, 10, and 15 years ago, meet present-day requirements, and with some rearrangements, will take care of those likely to develop tomorrow.

The detailed planning of program transmission circuits requires consideration of:

1. The numbers of circuits likely to be required, section by section, over each route;
2. The provisions for reliability, flexibility, operation, and supervision essential to a high-grade network service;
3. The transmission requirements, or electrical characteristics, necessary to achieve a natural reproduction of the program.

These three general classes of requirements will be considered in order.

Number of Circuits Required

The circuits which have been established on a full-time basis for continuing use form the backbone of the program networks. Even for these circuits, however, permanence is relative since frequent extensions and rearrangements are made to meet changing requirements of the broadcasters. Aside from these full-time circuits there are intermittent requirements occasioned by special events and other short-period needs of the broadcasters, some of which involve networks almost as extensive as the full-time networks. In addition reliability of service requires provision for rerouting the networks in the event of trouble. Figure 2 shows the year-by-year growth in the operated mileage of program circuits for the period 1926 to 1940. Of the more than 110,000 miles of circuits shown for 1940, about 45,000 miles have been provided for the short-period services and as stand-by facilities for protection. In addition to these, there are still other circuits, normally assigned to other services, which are arranged to be readily adaptable to program service to supplement the reserve facilities maintained on a full-time basis.

The time interval necessarily accompanying any extensive construction project makes it necessary to engineer plant considerably in advance of actual service requirements to meet, not only the expected growth, but also the changes in network routing. Figure 3 shows for two typical sections along major routes the variations in requirements for full-time network circuits resulting from growth and rearrangements required by the broadcasters. While, in planning to meet these rapid variations in circuit requirements, advantage can be taken of some latitude which exists in the choice of routes for occasional services and protection facilities, the task of balancing the provision of circuits against requirements is an entertaining and at times difficult one for the circuit engineer.

Operating Requirements

Considering for a moment the variety of programs originating at many different

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The authors of this paper gratefully acknowledge the assistance in its preparation of many of their associates, especially W. E. Bloecker, D. K. Gannett, and G. S. Bibbins.

1. For all numbered references, see list at end of paper.

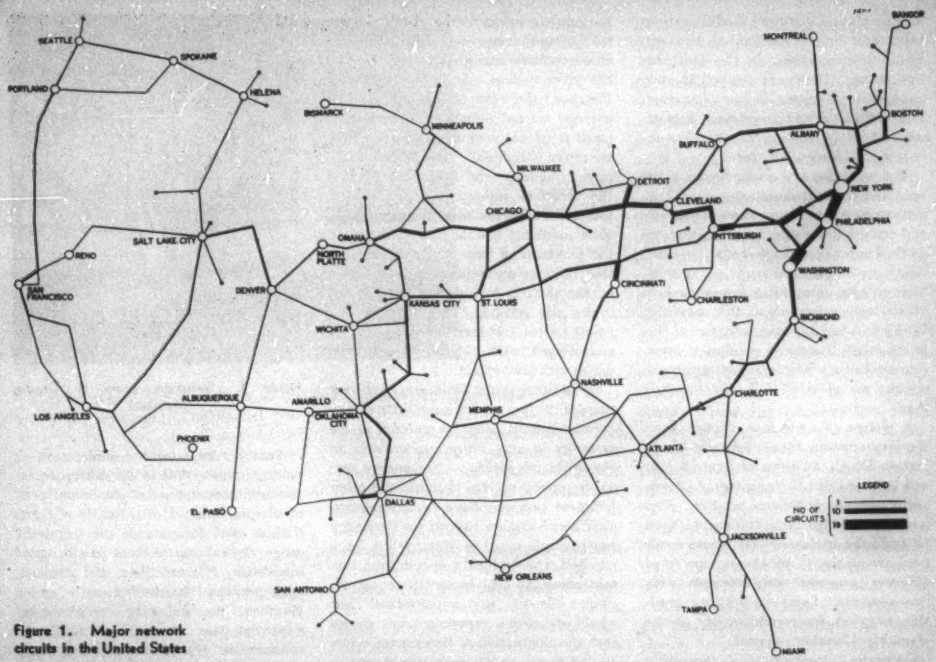

Figure 1. Major network circuits in the United States

points that can be heard on any home radio set in the course of an evening without once changing the tuning, it will be apparent that minute-to-minute rearrangements of an established interconnecting network must be possible. For example, studios have to be changed from receiving to originating, sections of the network have to be made to transmit first in one direction and then in the other, and branches have to be connected and disconnected. These changes in the network have to be made in the few seconds elapsing between the close of one program and the start of the next on the receipt of selected cue words or sounds. Even during the course of a single program, switches or reversals may have to be made to change the originating point temporarily. To provide for these rapid changes, special operation and special switching and reversing equipment are required at many points along the network. Much of this equipment is under remote control from selected points.

The greater portion of the switching of program circuits is done at about 25 points throughout the country on the major networks. On the average more than 25,000 switching operations per month are performed at these 25 points. During the busy hours of any typical evening there may be something over 500 men on duty at all of the offices about the networks.

At points where switching requirements are simple, the switching equipment consists merely of a few keys. At the larger points where the switching requirements are complex, the switching equipment consists of elaborate relay and control arrangements. These are so designed that it is possible to set up in advance the circuit combinations required for the ensuing program period without disturbing the programs in progress. The actual switching operation takes place at the instant the monitoring attendants signal the receipt of the last of selected cues, and not before then. This type of arrangement affords a maximum of protection against error, as it is possible to check the presetting for the next switch or make a last minute change if necessary any time before the switch has been made.

Figure 4 shows a picture of such a switching arrangement in use at Omaha, Nebraska for one broadcasting company.

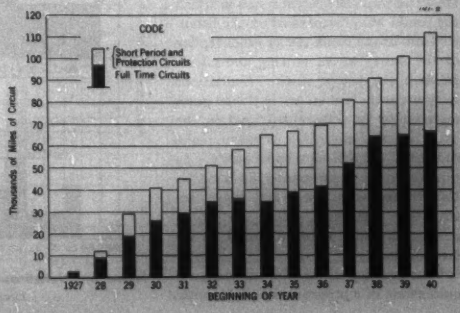

Figure 2. Growth in mileage of major network circuits

At this point 13 circuits used in various trunk and branch sections of two networks are connected to the switching equipment. These are grouped in various combinations to take care of as many as five simultaneous programs. A maximum of five cues might, therefore, be involved in a switch at this point.

The operation and maintenance of the networks are carried out by a special organization under centralized authority and trained in the application of uniform methods and procedures found by experience to be productive of best results. Transmission is monitored continuously at strategic points about the networks. In order to facilitate the activities of this group many thousands of miles of intercommunicating telephone and telegraph circuits are provided full time for their use.

A picture of a monitoring position in the program transmission office at Washington, D. C. is shown in figure 5. It will be noted that the monitoring attendant is using an individual headset. This is of a special high fidelity type and is used to avoid the confusion that would result from attempting to monitor a number of different programs simultaneously with loud-speakers. Loud-speakers are available, however, for supplementary checks of quality whenever required.

Accurate transmission measuring equipment is necessary at the various operating points about the networks to insure satisfactory transmission maintenance results.

Transmission Requirements

The general transmission requirement for a broadcasting system is that the program material be transmitted with a high degree of naturalness. Although the exact determination of the transmission characteristics which would accomplish this involves many considerations it will be assumed in this discussion that an ideal transmission system is one in which the sound waves impressed on the listeners' ears in the home are an exact replica of the sound waves striking the microphone in the distant studio. Limitations inherent in the human ear, in the program material to be transmitted, and in the usual listening conditions, however, make such ideal transmission unnecessary. In expressing the requirements for satisfactory transmission, frequency range, attenuation distortion, delay distortion, nonlinearity and noise are used as indices of quality.

Before taking up the transmission requirements of a program circuit, it is important to consider further the fundamental factors that are involved in fixing the characteristics considered desirable for the entire system. According to Harvey Fletcher,[4] the zone of audibility of the average normal human ear for pure or single frequency sounds is the area within the curve of figure 6. The abscissas represent frequency and the ordinates show the range of intensity recognizable as sound, between the lower limit or threshold of audibility and the upper limit where the sensation of pain is felt. It is seen that the extreme frequency range shown on the chart is from about 20 to 20,000 cycles per second. This range is for young people. It is considerably less for middle-aged and elderly people, and varies with individuals.

In addition to the limitation of the ear there is the fact that there is little energy present in most program material in the extremes of this range, particularly in the upper frequencies. The energy versus frequency spectra of music and other forms of program have been published elsewhere.[5] Figure 7 shows the frequency range which must be transmitted for a number of instruments, speech, and certain noises, so that competent observers cannot detect any impairment.[6] For whole orchestras, experiment has shown that the elimination of frequencies below 40 and above 15,000 cycles per second is undetectable.[4] If the upper limit of the transmitted frequencies is lowered from 15,000 cycles, the impairment is at first barely detectable but increases at an accelerating rate. When the limit is materially lower than 8,000 cycles, the loss is readily apparent to many people.

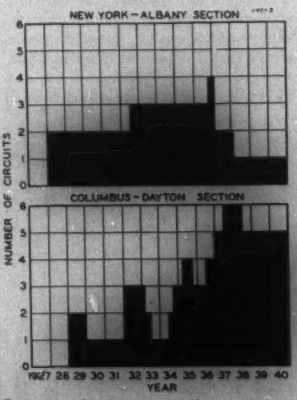

Figure 3. Variations in full-time program circuits

Figure 4. Switching panel at Omaha, Nebraska

Another important consideration is volume range—that is the difference between the maximum and minimum levels of the program. The ordinates of figure 6 show that for part of the frequency range, the ear can respond to a range of intensities of more than 120 decibels, with perhaps 100 decibels as a mean. However, the following considerations show that the volume range which the transmission system needs to accommodate is considerably narrower than the intensity range to which the ear can respond.

In the first place, the range of program volumes to which the ear can respond is much less than the range of single-frequency intensities shown by the curve. Program waves are in general very irregular in shape, and even at constant volume contain large and small peaks differing in amplitude by many decibels. The range between the volume at which the highest peaks reach the maximum instantaneous intensity which the ear can tolerate and the volume at which the smallest peaks are just above the threshold of audibility is therefore less by a number of decibels than the intensity range of the ear as measured by single frequencies.

In the second place, the volume range of the usual program material has definite limits. Measurements have shown that a large symphony orchestra produces a maximum volume range of about 70 decibels.[4] The volume range of most other types of program is considerably less than this, for example, being only about 25 to 30 decibles for dance music and as little as about 15 decibels for much of the dialogue of actors in radio drama.

In the third place, the usual listening

Figure 5. Monitoring position at Washington, D. C.

conditions impose a definite limit on the useful volume range. The loudest passages in the music of a symphony orchestra correspond to a sound level of about +95 decibels at a point, say one-third the way back in an auditorium, but most people in their homes prefer a level which is lower than this by 5 to 10 decibels. Figure 8 shows the results of an extensive survey[7] of acoustic room noise in homes. It will be noted that the average noise level is +43 decibels on the sound-level scale, and that few homes are quieter than +30 decibels even in the suburbs. The signal-to-noise range inherent in the listening conditions, and allowing nothing for the noise contributed by the transmission system or the room noise where the program is being produced, is therefore seen to be somewhere between 45 and 65 decibels. There is therefore, no advantage to the listener in providing a permissible volume range materially wider than this in the transmission system.

The above discussion applies primarily to the transmission of symphonic and similar high-grade program material. Much program material is less exacting in its requirements, but on the other hand some sound effects such as the tearing of paper require the reproduction of higher frequencies for complete naturalness.

With these broad considerations in mind, the requirements of high-quality program circuits may now be taken up. As has been noted, the program network is but one part of the over-all broadcasting system which, in addition, includes microphones and studio equipment, radio transmitters, and the home receivers with their loud-speakers. It may be taken as a goal for the program networks that their transmission be nearly enough distortionless so that the over-all performance in regard to naturalness of reproduction will not be limited by them.

To meet such a requirement for short program circuits having only one or two sections is not difficult technically, and does not in general require costly types of plant. However, the vast country-wide program networks are made up of many sections of circuits in tandem, which as mentioned before may total in some cases as much as 7,000 miles. This makes it necessary to design and operate the individual circuits to very close limits so that the cumulative discrepancies in the whole network will not exceed tolerable values; and to consider carefully the types of plant employed lest by virtue of sheer numbers of units involved, the total cost be out of line with the over-all grade of service being given the listener. These two conflicting factors are important ones in the consideration of transmission requirements for networks. The determination of the practical working characteristics of program networks involves a consideration not only of the physical and cost factors discussed above but also of such other factors as cost of studios, broadcast transmitters and receivers, and the limitations of the frequency allocations of broadcast stations.

From the standpoint of frequency band the consideration of all factors has resulted in the major present-day program networks being set up to transmit a frequency band with an upper limit of about 5,000 cycles. All program facilities installed in the last ten years or so, however, have been designed to be adaptable to the future transmission of frequencies up to 8,000 cycles. Operation on an 8,000-cycle basis, however, requires the release of additional frequency space now occupied by other services in much of the plant and a general readjustment of the program-circuit characteristics. In 1933, experimental wire circuits were set up between Philadelphia and Washington to transmit frequency bands up to 15,000 cycles. These were employed in a demonstration of stereophonic transmission and reproduction of music.[4] Studio-transmitter loops have been provided to transmit wider frequency bands than the 5,000 cycles currently provided on the nation-wide networks. At the present time, many of the studio-transmitter loops are being set up to transmit bands up to 15,000 cycles. A demonstration will be given at the close of the paper of the transmission of programs over cable circuits about 1,200 miles in length with frequency bands extending to 15,000, 8,000, and 5,000 cycles. The 5,000-cycle circuit is of the type in present commercial use. The 8,000-cycle circuit is of a type to which much of the present program plant can readily be modified. The 15,000-cycle circuit consists of a standard carrier system to which has been added program terminal equipment now under development.

In the consideration of transmission requirements for program circuits other than nominal frequency band, the varia-

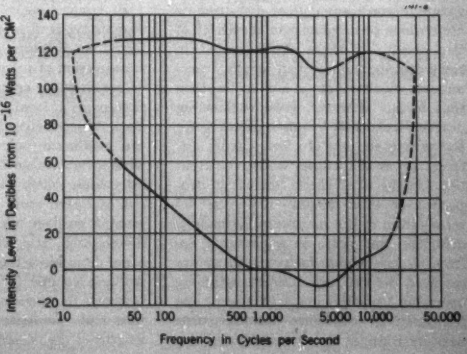

Figure 6. Limits of audible sound

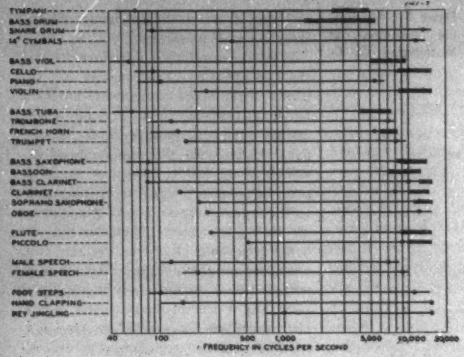

Figure 7. Audible frequency ranges of music, speech, and noise

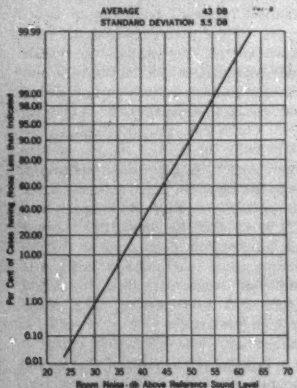

Figure 8. Residence room noise with radio sets silent

tion in performance with length and type of circuit is important, since the factors tending to impair transmission are in the nature of small amounts of distortion or noise which accumulate over the length of the circuit. If these effects varied in some definite manner with length, transmission requirements could be fixed on that basis. However, good engineering practice frequently requires choosing for the various sections of a long circuit, different types of facilities whose contributions to the total effects are not in proportion to their length. Even the determination of the maximum permissible distortion and noise on a circuit is influenced by outside factors such as are involved in the broadcasters weighing operating flexibility and cost against the frequency of occurrence of unfavorable network routings and the number of stations affected. For example, in order to secure operating flexibility with a minimum of total network mileage, most of the networks employ the so-called "round robin" principle for a part of the network. In this arrangement the circuit follows a route from station to station forming a continuous loop which returns to its starting point. This naturally results in increased circuit mileage between the program source and the more distant listeners with an attendant increase in undesired transmission effects. For these reasons no exact or specific transmission requirements can be stated for even the over-all performance of program transmission service.

Volume Range

The permissible volume range for a program circuit is determined by the maximum volume which can be transmitted as limited by nonlinear distortion or cross talk, and the minimum volume which can be transmitted without impairment from the noise present on the circuit.

In connection with their design the various types of program circuit are subjected to listening tests in which the transmission of program over a long loop of the circuit is compared with transmission over a local distortionless circuit. Each type of circuit thus is rated as to the maximum volume it can transmit without noticeable distortion. The highest volume which can be permitted without excessive cross talk into other program or message telephone circuits is also investigated, and whichever limit is the lower determines the maximum allowable working volume for service. The range between the maximum permissible volume and the noise level on very long lengths of the present program circuits is about 45 or 50 decibels, except under some conditions on certain open-wire sections. On the individual links making up the long circuit, the range is 10 or 20 decibels greater than this.

Attenuation and Delay Distortion

Another important consideration is the amount of attenuation and delay (or phase) distortion to be permitted within the transmitted frequency band. It is the practice to equip program circuits with adjustable attentuation equalizers. By means of these once the desired frequency band has been chosen the deviation in attenuation at any frequency within that band, compared with that at 1,000 cycles, can be adjusted within close limits. On very long circuits, however, experience has shown that even with automatic regulating features and careful operation residual variations which may amount to several decibels may develop as a result of changing temperature and other conditions. These variations are kept within tolerable limits by readjustment of the equalizers from time to time.

Associated with the attenuation distortion is another effect detrimental to program quality, namely, differences in time of transmission for different frequency components of the signal. In practice circuits tend to have a lower velocity of transmission near the edges of the frequency band than in the middle portions. This results in frequency components near the edges being delayed as compared to the middle portions of the band. This difference in time of transmission is called delay distortion of the circuit. Careful listening tests have shown that it becomes noticeable if, at the highest transmitted frequency, the delay is more than eight milliseconds greater than at 1,000 cycles, and if, at 100 cycles, it is more than about 15 milliseconds greater than at 1,000 cycles. It is controlled by careful attention to the design of loading systems, amplifiers, repeating coils, and all other elements of the circuit. Since such small amounts of over-all delay distortion are detectable and since networks frequently have 100 or more amplifiers in tandem between an originating point and the broadcasting stations on the more distant portions of the networks, it is necessary that the delay distortion of all individual components of a network be held to exceedingly close limits. Accumulations of residual delay distortion which cannot be entirely eliminated in design are reduced by the use of delay equalizers along the circuits when they are set up.

Prime-Mover Speed Governors for Interconnected Systems

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Synopsis: System operating requirements, from the standpoint of frequency and tie-line loading, are continually becoming more rigorous and receiving more widespread attention. Supplementary controls have been developed to assist in the solution of these problems—but the speed governors of the prime movers still constitute the backbone of system control.

This paper outlines the general problems encountered; gives definitions of terms for both steam and hydro governors and discusses the performance characteristics of these two general classes of prime movers. As a result of discussions with several operating groups certain definite conclusions were reached for prime-mover governor characteristics on the larger systems, viz., dead band should be as small as practicable; uniform incremental regulation desirable; adjustable regulation not necessary; similar rates of response not necessary and accurate response to supplementary control desirable. These conclusions are supported by the analytical work presented in the companion paper.[7]

A summary of the reasoning supporting these conclusions under the subjects of stability, dead band, regulation, response, short circuits, and tie-line swings is included.

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The authors wish to express appreciation to the representatives of the operating companies who contributed during the several discussions on this subject and to acknowledge the assistance of Messrs. C. Concordia, S. B. Crary, and E. E. Parker of the General Electric Company in the preparation of this paper.

1. For all numbered references, see list at end of paper.

Introduction

DURING the past several years the interconnected power system has come into being and has expanded rapidly to the point where some of these systems now comprise several million kilovolt-amperes of connected capacity. Many problems have appeared and of these, two important and closely associated ones, speed and load control, have continued to receive increased attention. In most cases large portions of these systems are tied together by tie lines of relatively small capacity and as a result power flow across the ties must be carefully controlled.

Frequency control is being widely used in varying degrees of refinement and automatic tie-line control is being used in more and more locations.[1,12,13,14] The control associated with these two problems is usually applied in the form of relatively slow supplementary adjustments to the normal action of the basic speed governors, which still constitute the backbone of system control. It is logical, then, as system operation becomes more refined and the requirements more rigorous, that more attention[2,3,4] be given to the characteristics of the speed governing mechanisms. During this same period special instruments[8,9,10] for accurately measuring small changes in system frequency have been developed and these instruments have been used to advantage by several groups in analyzing governor performance.

The manufacturers of power generating equipment endeavor to equip their prime movers with suitable governing equipment.[5,6] Also, in the analysis of power system performance it is essential to appreciate the influence of all associated apparatus, including speed governors[11,15] on system performance. On this basis, the general problems associated with speed governing were discussed with several operating groups, and with the evidence procured so far, we have reached certain definite conclusions as to what characteristics prime mover governors should have to meet the operating requirements on the larger power systems.

Definition of Terms

There is a surprising lack of a common language for this subject and thus, before proceeding further a brief definition of terminology used *in this paper* will be in order. Two sections in the ASME—Power Test Codes for Governors and Committee on Industrial Instruments and Regulators—each have a set of definitions and this is no attempt to

Conclusion

From this discussion it is seen that the program networks are comprised of many parts, each of which must meet exacting requirements in order that over-all results will be satisfactory. It is seen that equally important with transmission are the requirements for plant flexibility, adequate reserves, uniform practices, and centralized supervision of the networks.

The features discussed have been those found desirable for present-day network service. As indicated earlier, consideration of the needs of the future as well as those of the present is an essential feature of the design and engineering of the plant for program-network service. As a result of having done this it will be possible to provide with present plant, and with new plant currently being installed, adequate network facilities as the broadcasting art develops toward higher standards of performance. With the past experience as a guide, it appears that there should be no fundamental difficulty in meeting all reasonable requirements, always remembering that in the long run, requirements and costs bear definite relations to each other.

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arbitrate any differences, or establish new terms. A final decision on terminology will be reached through mutual agreement between representatives of manufacturers and operating groups both in the AIEE and ASME as well as other contributing groups.

Speed governor shall include the speed responsive element which positions a member in terms of speed. In figure 1 this is schematically represented by a conventional spring-restrained centrifugal flyball mechanism, but an oil pump working against a spring loaded diaphragm or a resonant circuit producing a torque motor effect will perform the same function.

Control mechanism shall include all linkages, pilot valves, dashpots, operating cylinders, cam shaft, cams and valves necessary to control the prime mover input in terms of speed governor position. In figure 1 a single pilot valve is shown between the speed governor and the operating cylinder. As the required pilot-valve size increases, a larger and more powerful speed governor is required. Instead of this, a relay mechanism or amplifier consisting of an intermediate pilot valve and piston is often interposed between the speed governor and the main pilot valve.

Governing mechanism shall include both the speed governor and control mechanism all as shown schematically in figure 1.

Over-all regulation is the sustained per cent change in speed of a prime mover for full load change from an initial speed of 100 per cent.

The regulation of the mechanism shown in figure 1 may be changed by varying the ratio of linkages, but there is always a lower limit for regulation below which stable operation cannot be obtained. This limit is determined by system conditions as well as by governor mechanism characteristics—but other conditions being similar, faster mechanisms permit smaller regulation with stability.*

Operating piston times for steam units are in the order of one second or less—whereas servo-motor times in hydro units are four seconds or greater to satisfy hydraulic conditions. Thus, if this simple mechanism in figure 1 were employed in a hydro governor, the regulation required for stability would be so large that other operating requirements would not be satisfied.

The manufacturers of hydro governors have solved this problem very neatly by employing droop correction as shown in figure 2. For sudden changes the dashpot

*Figure 3, reference 7.

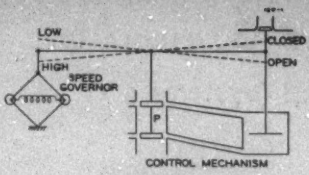

Figure 1. Schematic diagram of speed governing mechanism

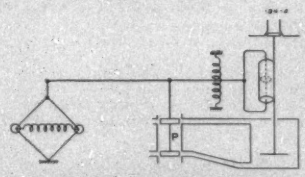

Figure 2. Schematic diagram of speed governing mechanism with compensating dashpot for droop correction, arranged for zero droop

acts as a rigid connection—giving broad transient regulation for stability, but after some time delay, the action of the dashpot and springs produces a much smaller steady-state regulation. In the figure, zero steady-state regulation is shown, but for paralleling purposes, the necessary amount of over-all steady-state regulation is obtained by positioning the spring supports in terms of operating cylinder position. Thus, droop (the remaining droop after the correction has operated) and over-all regulation are synonymous.

Incremental regulation is the slope of the speed-kilowatt curve passing through 100 per cent speed at the load in question, expressed in per cent of rated speed.

Unfortunately the uniform characteristic shown in figure 4 is not so easy to obtain and requires proper co-ordination in the design of both the speed-position characteristic of the governor and the flow-travel curve of the control mechanism. In the case of a hydro unit, the increase in flow for increased gate openings tends to fall off at the larger gate openings. In this respect most steam turbines have several inlet valves, each having its flow-travel characteristic. A comparison is shown in figure 3 where the dotted curve applies to a hydro unit and the solid curve to a four-valve steam unit.

Mechanisms as in figure 2 have both transient and steady-state incremental regulation. As far as governor influence is concerned, load division between units on a system is determined initially by transient incremental regulation and subsequently by the steady-state incremental regulation. Since most load changes on the larger systems are relatively slow, steady-state incremental regulation is the significant characteristic.

Dead band is the magnitude of the sustained speed change within which change of prime mover input will not be produced. Figure 4 shows two governors with equal dead band, one having broad and the other narrow over-all regulation. It may be seen that the governor having broader regulation will hold its load within a smaller range for a constant frequency and for the same frequency dead band, than the governor with narrow regulation. This dead band is a measure of the sensitivity of the mechanism. A method of simultaneously recording speed on one axis and mechanism movement on the other axis has been developed using apparatus similar to that described in reference 8. When proper interpretation of such records can be made, this method should prove useful in determining the over-all dead band of governing mechanisms while in service.

Supplementary adjustment—Any means employed to adjust externally the prime mover input.

Conclusions

The following conclusions, which apply to the requirements of both steam and hydro units, have been arrived at after having considered operating requirements, nature of load changes on large systems, reliability of operation, simplicity in mechanisms, and ease of maintenance.

1. Dead band should be as small as practicable.
2. Uniform incremental regulation is desirable but not essential.
3. Adjustable regulation is not necessary.
4. Similarity of rates of response is not necessary.
5. Accurate response for supplementary adjustment is desirable.
6. Indications of all adjustments are desirable.

A brief review of the reasons supporting the above conclusions follows:

Stability

One of the first and axiomatic requirements is that the mechanism be stable** at all times. A stable governor is one which does not by itself produce or excite an oscillation. A governor with a high degree of, or with good stability, is effective in quickly reducing the magnitude of an oscillation produced by any disturb-

**Figures 1–12 inclusive, reference 7.

ance. Small dead band, broad incremental regulation, both transient and steady-state, and small time lags all contribute to stability and are largely under the control of the designer. Generally, if the unit is stable for synchronizing, it will be still more stable when connected to a system due to the synchronizing and damping torque action provided by the system. For the same reason a governing mechanism which is poor when operated alone may give no trouble when it becomes part of a system already equipped with good governors.*

At the same time a single machine or a number of machines behaving as a group is influenced to a large extent by the damping characteristic of the load, i.e., the change of load per unit of speed change, other conditions being constant.**

Dead Band

Small dead band (small over-all insensitivity) contributes to stability, maintains accurate loads at fixed frequency and gives accurate response to frequency variations. (See figure 4.) Study of this characteristic has convinced us that it is the over-all dead band, rather than dead band of some particular portion of the mechanism, that is the significant factor.†

In a few instances there has been evidence to show that if insensitive governors control the major portion of the system, speed variations may be aggravated by either unnecessary movement of the mechanisms or by insufficient movement caused by the dead band allowing a greater change in frequency before the proper input correction is obtained. These conditions can be overcome by improved design in available mechanisms.

Present evidence indicates that over-all dead band should be made as small as possible just so long as the effort is not carried to the point of requiring undue expense in manufacture, and of requiring undue maintenance in the field to keep that degree of performance. Operating groups can, by tests and analyses, assist the governor designers in establishing the proper economic limit.

Incremental Regulation

The incremental regulation in the normal operating range should be as uniform as is consistent with economical design of the mechanism and efficient turbine operation. By making the incremental regulation as uniform as possible and as large as necessary, stability

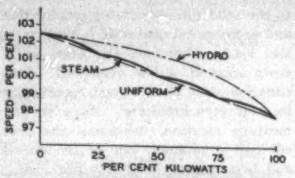

Figure 3. Typical speed-load characteristics for steam and hydro units. Slope of curves at any point is incremental regulation

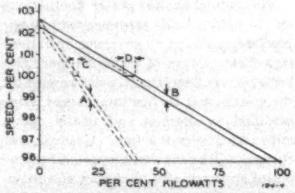

Figure 4. Speed-load curves showing dead band. A and B—Possible speed variation within dead band. C and D—Possible load variation within dead band

margin at all valve points is assured and more uniform response to supplementary adjustment is obtained. If the improved uniformity is obtained entirely through mechanism design, more powerful operating cylinders may be necessary or more complicated mechanisms may be required. If the improved uniformity is obtained by increased overlapping in the valve openings, the turbine efficiency is reduced at the valve openings.

Incremental regulation should be as broad as is consistent with reasonable system speed variations. Broad regulation improves stability, contributes to most rapid settling down after a disturbance, and minimizes any tendency for hunting which might be caused by dead band.

Regulation

For steam turbines the maximum over-all regulation which can be tolerated and still meet the present overspeed and emergency trip requirements is about six per cent, and the minimum over-all regulation for stability is in the order of two or three per cent without droop correction. For this reason it is believed that some reasonable over-all regulation in this range can be used for most steam turbine mechanisms, thus avoiding the added complication of adjustable regulation. An advantage in operating on small over-all regulation might be to reduce slightly the duty on the supplementary corrective devices now employed, but it appears as though there is a good chance of creating a wider frequency fringe by attempting to operate the units of an entire system on small over-all regulation, because of the reduced degree of stability obtained.‡

As previously mentioned, hydro governors ordinarily use a large transient regulation in order to obtain stability and droop correction to obtain reasonably small steady-state regulation. Adjustment of this droop is readily obtained. Where adjustable regulation for steam turbines is considered desirable, it may be provided in two ways; first, with a simple mechanism similar to figure 1 where the linkages are adjustable over the two to six per cent range; second, by adding speed droop correction, figure 2, which permits over-all regulations as low as zero, on one machine.

For smaller systems the per cent load changes relative to system capacity are usually larger and maintaining speed is more of a problem. In these cases governing mechanisms which can, if desired, be operated at zero steady-state regulation have a distinct field of usefulness. It is believed, however, that while mechanisms are being built to meet these special conditions on smaller systems, the conditions on the larger systems do not demand such flexibility in speed governing mechanisms.

Rate of Response

The present rates of response of steam and hydro governors are widely different, and this results in a corresponding redistribution of power flow subsequent to load changes. Usually, the sudden load changes on most large systems are relatively small and the major load changes occur at a rate which can be followed by even the slowest mechanisms. In an interconnected system, all active governors respond to all load changes regardless of location in proportion to their ability, and in principle it is the function of supplementary control (manual or automatic, or both) finally to allocate a load change in any area to generation in the same area. Any redistribution of load due to different governor characteristics is so masked by real load changes that it is not considered important to modify designs in order to match characteristics.

Matching characteristics of steam and hydro units would mean slowing down steam turbine governor response to approach that dictated by hydraulic limitations on hydro units, whereas actually in

*Figure 11, reference 7.

**Figures 3 and 4, reference 7.

†Table 1, reference 7.

‡Figures 3 and 14, reference 7.

the interest of limiting overspeeds and improving stability it appears desirable to make steam governor response as rapid as is possible without complicating the mechanism. However, in this regard there is no necessity of attempting to make governors which are responsive to rate of change of speed, e.g., inertia governors, since overspeed and stability requirements can both be adequately met with a pure speed responsive mechanism.

Terminal frequency has been suggested to provide speed indication for the governor. This method has no advantages so far as performance is concerned over using shaft speed, but it does have at least two distinct disadvantages, both based on the probability that during out-of-step conditions, it may not indicate the actual speed of the unit. As a result, first, in the case of a turbine generator, a separate pre-emergency device to prevent tripping the emergency on overspeed would be required; second, the unit is not intelligently helped to pull back into step. The use of terminal drive has been generally limited to small hydro machines in locations where these disadvantages are not important.

System Short Circuits

In transient stability calculations of systems (studies of the ability of generators to remain in synchronism after a disturbance), governor performance is usually neglected and this assumption gives only slightly pessimistic results for the amount of power which can be transmitted through a short-circuit disturbance.

Fast switching is being commonly used and with breaker speeds now commercially available, stability during short circuits at practical loadings for transmission lines is possible, so that very little gain can be expected through improved governor performance during this short interval. The governing mechanism will do its share if it assists in damping out the subsequent synchronous oscillation.

Out-of-Step Conditions

Out-of-step operation has occurred usually as a result of too slow clearing of a severe fault. When the fault is finally cleared, the generator or station is running faster than the rest of the system. If hydro units are involved, large overspeeds may occur, and system relays will probably trip on overcurrents before the units will resynchronize themselves, even if supplementary means are employed.

Steam units, on the other hand, have faster governing mechanisms, much better induction torque characteristics due to the solid rotor generator construction and a stronger electrical tie to the system and load. Therefore, the units settle down soon at a low overspeed. This situation alone gives a good opportunity for self-resynchronizing. As a supplementary measure, increasing the field strength is probably one of the easiest and best assurances of resynchronizing, although some have advocated reducing the input torque.[16]

Tie-Line Load Swings

The normal tie-line power fluctuations due to sudden load changes cannot be appreciably reduced by governor operation, regardless of rate of response, since the initial power flow is largely determined by the system and tie-line impedances, later modified by inertias and finally determined by governor action. Gradual load changes will be divided according to composite governor characteristics of various portions of the system and later modified by supplementary control.

In the steady-state condition most tie lines have a sustained power oscillation at the natural frequency of the interconnected groups. These power oscillations are usually a small percentage of the tie-line capacities and alone represent no problem. With these power oscillations there is associated a speed oscillation of small magnitude. Experience and our studies[7] indicate that the characteristic of these swings may be influenced by governor action, but usually should be within reasonably satisfactory limits with ordinary governor performance. In those cases where the governors tend to excite unnecessary power oscillations, proper adjustment of the governor characteristics, for example, broadening the regulation, should eliminate the tendency.

Adjustment and Indications

Supplementary adjustment is provided on all speed governors and may be used for either manual or automatic correction. This adjustment should be arranged so that reasonably uniform response is assured throughout the operating range.

Gate position indication has been available on hydro units for some time and indication of operating piston position on steam units, with valve opening points marked, has been suggested. Gate indication on a hydro unit is often more useful than a wattmeter, particularly on a variable head installation and on a steam unit it is desirable to avoid operation at partial valve openings. With the more recent turbines a recorder is being provided which records speed of the unit prior to synchronizing and which records cam shaft position after synchronizing. This arrangement gives a complete record of the manner in which the machine has been brought up to speed and loaded.

Load-limiting features are furnished on most turbines and are still being used to some extent. This feature is particularly useful in maintaining a fixed load on a machine connected to a system where the frequency is allowed to vary through wide limits. On most large systems, today, frequency is normally held within a 0.1-cycle band by means of supplementary control. Any machine equipped with a five per cent speed governor will change load by only three per cent in response to such a frequency change and most steam operators agree that this is essentially fixed load, for machines carrying a reasonable load. In general, the frequency fringe on a system is reduced by increasing the percentage of machines on governor control, and to this end load limit as such may be advantageously discarded except as a back-up measure to prevent severe overloads on boilers and associated equipment during system emergencies.

Summary

The conclusions which have already been enumerated and discussed apply to governing mechanisms of prime movers on the larger systems. For smaller systems governing mechanisms which can, if desired, be operated at zero steady-state regulation, have a distinct field of usefulness. For governing mechanisms on the large systems, emphasis should be placed on obtaining uniform incremental regulation, accurate response for supplementary control, and small dead band. The experience and judgment of the operating groups will be of assistance in determining the economic limit, beyond which the design cannot be justifiably carried.

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Analysis of Short-Circuit Oscillograms

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Summary

METHODS of analyzing the oscillograms of short circuit currents of synchronous machines, in accordance with the two reaction theory, are presented in this paper. Differences between the results found here and the more generally accepted equations, based on symmetrical components, are pointed out.

Introduction

The analysis of short circuit oscillograms to obtain synchronous machine reactances is usually made by means of the equations developed from symmetrical component theories. These equations have been employed by previous writers on the subject and have been incorporated in published standards. Because symmetrical component methods usually start from the assumption of sinusoidal currents of single frequency in the armature, and because it is known that short circuit currents depart appreciably from the simple sinusoidal form, it is desirable to know the effect of removing the assumption of sinusoidal currents on the equations used in the analysis of short circuit oscillograms.

The two reaction theory of synchronous machines, as developed by Doherty and Nickle[1,2], permits a calculation of the harmonics of armature current. The method has been widely used to determine operating characteristics of machines; but the application to the calculation of machine quantities from oscillograms of short circuit currents is not well known. It is the purpose of this paper to show how the two reaction theory applies in such a determination of reactances.

The equations of armature current as previously published are restated here. From these equations, expressions for the envelopes of the currents are written. These envelopes have certain slight limitations which will be mentioned later, but, except in rare cases, they may be drawn readily on the oscillogram. The equations of the envelopes permit a simple statement of the relations between the voltages, currents and reactances.

The two reaction theory has been checked by test within the limits of the assumptions under which it was derived. The results herein described have about the same limitations and the same degree of applicability. While it is true that the presence of saturation, resistance and nonsinusoidal windings cause appreciable departures from the case of the ideal machine here treated, knowledge of the characteristics of the ideal machine is basal to an understanding of the effects of these complicating factors.

Three-Phase Short Circuit

Doherty and Nickle[2] give the equation of the armature current after a sudden three phase short circuit at the terminals of the machine. It may be shown that the current in one phase, when the effect of an amortisseur is included, is defined by the following equation.

$$i=\frac{e_0F_2}{x_d''}\cos(t-\alpha)-\frac{e_0(x_d''+x_q'')}{2x_d''x_q''}A_3\cos\alpha+\frac{e_0(x_d''-x_q'')}{2x_d''x_q''}A_3\cos(2t-\alpha)\ \text{times normal peak current} \quad (1)$$

where

i = per unit current at any time t.

e_0 = per unit voltage before fault (peak value).

t = per unit time, $t=0$ at time of fault. One per unit time is required for the machine to progress through one electrical radian.

α = electrical angle between centerline of armature and centerline of field at the time of the fault.

x_d = per unit direct axis synchronous reactance.

x_d' = per unit direct axis transient reactance.

x_d'' = per unit direct axis subtransient reactance.

x_q'' = per unit quadrature axis subtransient reactance.

σ_a = decrement factor of the armature.

σ_f' = decrement factor of the field, transient.

σ_f'' = decrement factor of the field, subtransient.

$A_3=\epsilon^{-\sigma_a t}$

$$F_2=x_d''\left[\frac{1}{x_d}+\left(\frac{1}{x_d'}-\frac{1}{x_d}\right)\epsilon^{-\sigma_f' t}+\left(\frac{1}{x_d''}-\frac{1}{x_d'}\right)\epsilon^{-\sigma_f'' t}\right]$$

Consider the case, $\alpha=0$, which gives a fully offset wave.

Subject to conditions stated later, two equations representing the envelope may be written as follows:

$$\text{Envelope line number } 1=\frac{-F_2-A_3}{x_d''}e_0 \quad (2)$$

$$\text{Envelope line number } 2=\frac{F_2-A_3}{x_d''}e_0 \quad (3)$$

It may readily be verified that the slopes and values of equation 2 at $t=\pi+2n\pi$ are identical with the slopes and values of equation 1 at $t=\pi+2n\pi$. Similarly, the slopes and values of equations 3 and 1 are equal at $t=0+2n\pi$. Therefore, unless there is more than one maximum per half cycle, they are the envelopes as usually defined. (This latter condition will be discussed later.)

The difference obtained by subtracting equation 2 from equation 3 gives the width of the envelope,

$$\text{width of envelope}=\frac{2F_2e_0}{x_d''}\ \text{(in terms of normal peak current)} \quad (4)$$

The d-c component of the current is given by the second term of equation 1. For a fully offset wave,

$$\text{d-c component}=\frac{A_3e_0(x_d''+x_q'')}{2x_d''x_q''} \quad (5)$$

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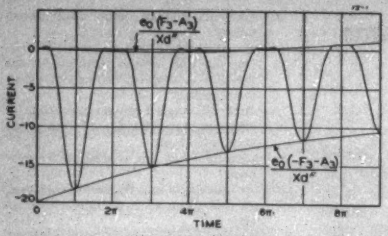

Figure 1. Three-phase fault current and envelope, equations 1, 2, 3

$\alpha = 0$
$x_d'' = 0.10$ per unit
$x_q''/x_d'' = 3.0$
$x_d' = 0.15$ per unit
$x_d = 1.00$ per unit
$e_0 = 1.0$ per unit
$\sigma_a = 0.0265$ per unit
$\sigma_f'' = 0.106$ per unit
$\sigma_f' = 0.0076$ per unit

This component is often considered to be traced by the midpoint of the envelope lines. That this is not the case is evidenced by averaging equations 2 and 3, which determines the midpoint:

$$\text{Median line between envelope lines} = \frac{A_2 e_0}{x_d''} \tag{6}$$

A study of equation 4, together with the expression given for F directly after equation 1, shows that the envelope width at $t=0$, when extrapolated from the subtransient region, is $2e_0/x_d''$; when extrapolated from the transient region it is $2e_0/x_d'$. These relations have been shown only for the case of $\alpha=0$, giving a fully displaced wave. They also hold at $\alpha=180$, but not for a fault at any other point in the cycle, unless $x_d''=x_q''$.

If the rates of change of the decrement factors, A_2 and F_2, in equation 1 (for $\alpha=0$) are assumed to be zero (in commercial machines they are small compared to the rates of change of the sinusoidal terms) the conditions for maxima and minima of current are:

$$\sin t = 0 \tag{7}$$

$$\cos t = -\frac{x_q''}{x_q'' - x_d''}\,\frac{F_2}{2A_2} \tag{8}$$

The roots of equation 7, substituted into equation 1, with $\alpha=0$, yield the envelope lines, equations 2 and 3. Equation 2 is derived by setting $t=\pi$, 3π, 5π, etc.; equation 3, by setting $t=0$, 2π, 4π, etc. These envelopes have previously been shown to pass through the maximum and minimum points (at 0, 180, 360 deg., etc.) of the current wave, and to have the same rates of change as the current at these points.

Roots of equation 8 exist only when

$$|2A_2(x_q'' - x_d'')| > |F_2 x_q''| \tag{9}$$

It is apparent that when $x_q'' - x_d''$ is small, only one maximum exists per half cycle. Under such conditions the envelope may be drawn on the oscillogram in the usual way and equations 2 and 3 will represent the envelope.

When the inequality (9) is satisfied, equation 8 can be solved and additional maxima are introduced. However, the envelope represented by equations 2 and 3 can still be drawn, and the relations derived from these equations still hold. The manner of constructing the envelope for such conditions is indicated in figure 1.

Calculation of peak currents may be made from the above equations. Consider the first negative peak of figure 1. It is apparent that the maximum current occurs just previous to the point of tangency with the envelope (the 180° point) and that for most purposes this peak value may be approximated by the value at 180°. From equation 1 or 2, this value is

$$\text{peak current} = e_0\,\frac{A_2 + F_2}{x_d''} \text{ times normal peak current} \tag{10}$$

Disregarding the small increase in this value mentioned above, the value of peak current given in equation 10 can be exceeded only if x_d'' is appreciably greater than x_q''. Under this condition the sign of the second harmonic is reversed and the double maximum which is shown in figure 1, near the 360° point, occurs near the 180° point. An examination of figures 1, 2, and 3 shows how the change of sign on the second harmonic component (see equation 1) changes the position of the double maximum. The condition, $x_d'' > x_q''$, is uncommon in commercial machines and need not be considered further.

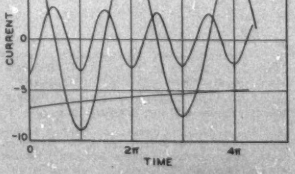

Figure 2. Components of figure 1

The above discussion and equations are valid only for the case $\alpha=0$ (or 180°), which results in a fully offset wave. For a fault at any other point in the cycle, no similar simple relations have been written. However, the extent to which the wave shape changes with change of α is indicated in figure 4. The envelope lines for the case, $x_q''=x_d''$, (where envelope width is $2F_2/x_d''$) are shown to indicate the amount of variation from the simple case which may be expected.

Single-Phase Case

Nickle, Pierce and Henderson[1] give the equation of armature current for single phase short circuit at the machine terminals:

$$i = \frac{3e_0}{k}\,\frac{F_1\cos(t+\alpha) - A_1}{H} \tag{11}$$

or,

$$i = \frac{3e_0}{2k}\,\frac{2F_1 O}{x_d'' + x_2} - \frac{A_1}{x_1}\,E \tag{12}$$

where

k = 1 for L-N, 3 for L-L fault

$H = (x_d'' + x_q'') + (x_d'' - x_q'')\cos 2(t+\alpha)$

$A_1 = \epsilon^{-\sigma_a t}\cos\alpha$

$$F_1 = \frac{x_d'' + x_2}{x_d + x_2} + \frac{(x_d'' + x_2)(x_d - x_d')}{(x_d + x_2)(x_d' + x_2)}\epsilon^{-\sigma_f' t} + \frac{x_d' - x_d'' - \sigma_f'}{x_d' + x_2}$$

$$O = \cos(t+\alpha) + b\cos 3(t+\alpha) + b^2\times\cos 5(t+\alpha) + \ldots$$

$$E = 1 + 2b\cos 2(t+\alpha) + 2b^2\cos 4(t+\alpha) + \ldots$$

$$b = \frac{x_2 - x_d''}{x_2 + x_d''} = \frac{\sqrt{x_q''} - \sqrt{x_d''}}{\sqrt{x_q''} + \sqrt{x_d''}}$$

$$x_2 = \sqrt{x_d'' x_q''}$$

For a line-to-neutral fault use $x_d'' + \frac{x_2}{2}$ for x_d'' etc.

Similar to the three phase case, the equation of the envelope of the single phase fault current is

$$\text{Envelope line number 1} = \frac{3e_0}{k}\left[\frac{-F_1 - A_1}{2x_d''}\right] \tag{13}$$

$$\text{Envelope line number 2} = \left[\frac{3e_0}{k}\,\frac{F_1 - A_1}{2x_d''}\right] \tag{14}$$

$$\text{The width of the envelope is } \frac{3e_0}{k}\,\frac{F_1}{x_d''} \tag{15}$$

The extrapolation of the subtransient part of the envelope to $t=0$ yields $\frac{3e_0}{kx_d''}$ times normal peak current. The extrapolation of the transient part of the envelope to $t=0$ yields $\frac{3e_0}{kx_d''}\,\frac{(x_d'' + x_2)}{(x_d' + x_2)}$

Similar to the three phase case, unless

$$-1 \leq \left[\frac{A}{F}+\sqrt{\frac{A^2}{F^2}+\frac{x_q''}{x_d''-x_q''}}\right] \leq 1 \text{ and is real} \quad (16)$$

the envelope of equations 13 and 14 is drawn in the usual way. If these conditions do exist, there will be more than one maximum per half cycle, but the envelope lines may still be drawn tangent at the 0° and 180° points, similar to figure 1, which treats the three phase case.

The peak value of the single phase fault current may be written from equation 13. The absolute peak value occurs when the wave is fully offset

$$\text{peak value of current} = \frac{3e_0}{k}\,\frac{F_1+A_1}{2x_d''} \text{ times normal peak value} \quad (17)$$

Certain limitations must be applied to equation 17 similar to those applied to equation 10 which governs the three phase case. Equation 17 can be used with confidence where $x_d'' < x_q''$; however, where x_d'' is appreciably greater than x_q'', the absolute peak value of current will occur before the 180° point (assuming a totally offset wave) and may be appreciably greater than the value given by equation 17. This possibility is pointed out but not investigated further because of the improbable nature of the condition.

Conclusions

1. In a single phase line-to-line short circuit the width of the envelope (in terms of normal peak value of current) extrapolated to the time of the fault is $\frac{\sqrt{3}e_0}{x_d''}$. The reactance, x_2, does not appear as it does in the symmetrical component method of analysis, $(2\sqrt{3}e_0)/(x_d''+x_2)$. In a single phase line-to-neutral short circuit the extrapolated value of the envelope width is $3e_0/(x_d''+x_2/2)$.

2. An extrapolation to the time of the fault of the transient part of the envelope of a line-to-line fault shows the width of the envelope to be

$$\frac{\sqrt{3}e_0}{x_d''}\,\frac{x_d''+x_2}{x_d'+x_2}$$

The above relations developed from the two reaction theory indicate that it is not possible to determine x_2 from the subtransient part of the envelope of the current of a line-to-line fault. Any attempt to use the transient part of the envelope to find x_2 is very liable to errors arising from errors in the determination of x_d'' and x_d'.

Similarly, unless x_0 is very large, its accurate determination from the envelope of current of a line-to-neutral fault is not practicable.

3. The peak current on a line-to-line fault is

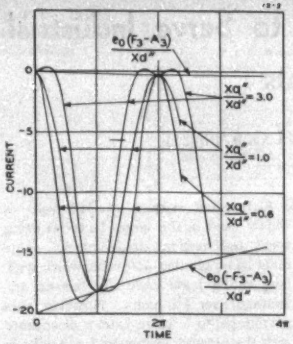

Figure 3. Change of wave shape with change of x_q''/x_d''

Other constants same as in figure 1

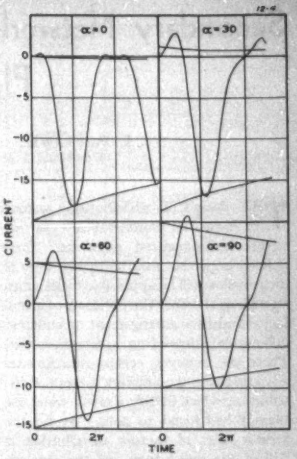

Figure 4. Change of wave shape with change of α

Other constants same as figure 1. See text for description of "envelope" lines

$\sqrt{3}e_0\frac{F_1+A_1}{2x_d''}$ times normal peak current, where A_1 and F_1 are decrement factors, equal to unity at the time of the fault.

The peak current of a line-to-neutral fault is $3e_0\frac{F_1+A_1}{2x_d''+x_0}$.

It is of interest to note that x_2 does not enter in the above expressions as it does in the equations resulting from the use of symmetrical component methods. In every case where $x_2 > x_d''$ the symmetrical component equations apparently calculate too low a value of peak current.

4. In an ideal machine, when the armature current in a three phase short circuit is fully offset, the envelope width at the time of the fault is $\frac{2e_0}{x_d''}$ times normal peak current when extrapolated from the subtransient region and $\frac{2e_0}{x_d'}$ when extrapolated from the transient region. In general, this is not true when the fault is made at any position of the rotor other than that which gives a fully offset wave.

In most commercial machines the ratios of machine constants are such that the degree of offset is of little practical importance in the determination of reactance from oscillograms of three phase short circuits. However, in view of the fact that several published statements prefer a symmetrical current wave, the above conclusions preferring a fully offset wave are of interest.

The conclusions given here are dependent on a prescribed method of drawing the envelope, which is explained in the body of the paper. In the majority of commercial machines this fact presents no great limitations.

The equations presented above are dependent on the assumption of an ideal machine: negligible resistance; negligible saturation; sinusoidal windings; and a sinusoidal variation of armature subtransient reactance with rotor position. The presence of resistance alters the phase relationship between the current harmonics, although it does not usually cause impedances to be appreciably greater than the associated reactances in short circuits at the machine terminals. Saturation may be partially treated by employing saturated values of the reactances; but the wave form distortion due to the changing values of reactance during the fault and the nonsinusoidal distribution of windings may cause appreciable departures from the calculated wave shape, and thereby vitiate in part the conclusions of this paper. However that may be, a more thorough understanding of the ideal machine relationships should be an aid to more accurate determination of synchronous machine constants from test.

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Secondary Networks to Serve Industrial Plants

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THE design of distribution systems for industrial plants will always constitute individualized problems. There is little hope that any particular form of distribution will be applicable to all industrial plants because the processes of manufacture and the arrangement of buildings differ widely depending on circumstances. There are, however, certain fundamental advantages to the network system of distribution which justify a much wider use than it has found to date. By far the greater part of factory distribution is still of the radial type and the network system must compete with the radial system in economy, reliability, and flexibility. The purpose of this paper is to show that it can do so successfully.

Assuming that the product of the factory is such that a relatively large number of small and medium-sized motors are required rather than a few large ones, it will be found that the physical location in the factory of the various machines is not of such importance in the layout of the distribution scheme as the total connected load, the diversity factor and the over-all power factor, and it is on its ability to take advantage of diversity that some of the economy of the network system rests.

The information available on the load density of factories is quite fragmentary. For the more common products of manufacture it varies from 5 to 30 kw per 1,000 square feet, 10 to 20 being the value mostly encountered, although in exceptional cases it may go as high as 100 kw. Load density should not be confused with the rating of the installed motors and utilization devices. The diversity between the various loads will considerably reduce this figure, and the "demand-factor," that is, the ratio of the maximum demand over a period of time to the sum of the utilization device ratings, which is of significance in determining the transformer capacity to be installed, may be 50 per cent or less.

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A nominal voltage of 440 volts is widely used in the larger factories using small and medium-sized motors. Some mills have adopted 550 volts which with long radial feeds naturally has an advantage over 440 volts. However, this advantage to a large extent disappears with the network system and 440 volts is preferable. Experience with 208-volt metropolitan networks indicates that motors of 750 horsepower and even larger can readily be started up on a 440-volt network without disturbance.

It is desirable that the 440 volts be maintained at the motor locations without much deviation either up or down, and since the regulation in the network is better than in most existing radial distribution systems, the voltage at the supply source should not be much higher than 440 volts.

In the conventional 208-volt city network, the lighting is carried out at 120 volts with the units connected between the outside conductors and neutral. With 440 volts maintained on the suggested factory network the same possibility exists if 250-volt lighting can be used with safety. The type of lighting that might be operated successfully on 250 volts would include primarily the high-intensity mercury lamps of 250- and 400-watt sizes in high-bay reflectors (figure 1), and for intermediate mounting heights the larger fluorescent lamps.

Figure 1. General lighting at an average intensity of 25 foot-candles supplied by three 40-watt daylight fluorescent lamps in each luminaire

It is generally found necessary in modern manufacturing methods to change tool machinery and processes around in the factory from time to time to meet market conditions, but it is also true that such changes cannot be of a radical nature as the manufacturing possibilities are limited by the type and size of the building. It is, therefore, advisable in designing the distribution system to make the power available at a number of points conveniently spaced throughout the factory building without too much regard to the detailed location of the individual tools.

The network is well adapted to supplying power to such points, and where the total load is 500 kva or more a network, either a distributed or spot network, will frequently be justified. As the total load increases the network becomes more decisively economical.

It is convenient to divide networks into spot networks and distributed networks. A spot network consists of a bus supplied through two or more network transformers and protectors over two or more primary feeders as shown in figure 2. It may be used in the smaller plants or large commercial buildings where the demand is relatively light and distances short. The distributed network on the other hand comprises a secondary grid, the junction points of which are supplied through network transformers and protectors from two or more primary feeders, as shown in figure 3. There is practically no limit to the load that can be carried on such a grid, and spot networks grow into conventional networks as the load increases.

It is not possible to lay down any definite rules regarding the number of supply points and secondary ties that should be included in factory networks, nor the best

size of copper to use. This will depend on the load density and arrangement of the manufacturing aisles in the factory buildings. It can be said, however, that when high current-carrying capacity is required in the secondary mains it is preferable to limit the size of conductor and use two or more smaller conductors in parallel instead of a single large conductor. For example, two 4/0 conductors in parallel provide more carrying capacity than a 500,000-circular-mil conductor and also provide better voltage regulation for a given current at the power factors usually prevailing in distribution systems. Furthermore, in case of a fault in one of these parallel cables, the limiters will isolate it without breaking the network.

The ease with which increasing loads or rearrangement of existing loads in the plant can be taken care of is one of the outstanding advantages of the network system. The addition of a transformer at a junction point of the grid can be made at any time without interruption of service, the relatively small self-contained transformer units with the network protector mounted on it requiring very little space.

Further advantages of the system are reliability, good regulation, and high economy. Reliability is improved by virtue of the fact that the grid is supplied from all the feeders supplying the factory and through all the transformers. The loss of a feeder or transformer would, therefore, pass unnoticed as far as the factory operations are concerned. The regulation is better and the disturbances due to starting up motors are less because of the multiplicity of paths over which the current flows.

In most factories supplied through radial systems of distribution it is usual to put in a substation at some convenient location with one or more transformer banks stepping down the voltage from the power company's primary distribution voltage. A full capacity primary circuit breaker and a 440-volt distribution bus are provided in the substation from which a number of radial feeders are run to the distribution centers in the factory through suitable circuit breakers. The disadvantages of this scheme are obvious.

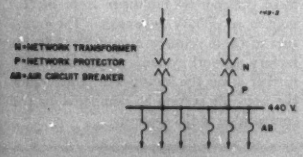
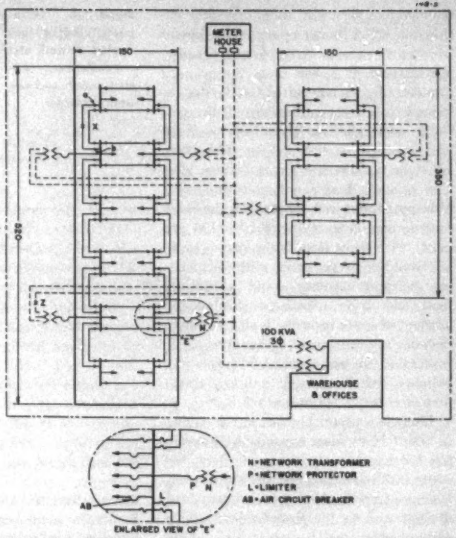


Figure 2. Spot network

Figure 3. Distributed network for factory buildings



All the breakers must have high rupturing capacity, the low-voltage, that is, the heavy-copper, feeders are of considerable length before reaching the utilization points and maximum economy is obtained only if it is known beforehand exactly what the power requirements are likely to be. Experience has shown that this assumption cannot be made and consequently the transformer capacity installed is usually very much greater than necessary.

A network for a typical factory consisting of two manufacturing and assembly buildings and a five-story office and warehouse building is shown in figure 3. The supply from the utility is over two cables at 13,200 volts, 60 cycles. The maximum demand is 2,500 kva. For taking care of the shop load six transformers of 450 kva, 13,200/440 volts, equipped with primary change-over switches and secondary protectors are provided, and for the warehouse load two 100-kva, 13,200/208-volt, network transformers.

The transformers may be standard oil-filled transformers with network protectors mounted on them, similar to those used in metropolitan distribution systems. In this case they will be placed outside of the factory buildings, either in the open or in vaults. In many cases a more economical installation can be made with air-cooled transformers placed inside the factory buildings, the transformers having mounted at one end an open-type network protector and on the other end a primary switch, the entire unit being enclosed in a single-ventilated housing as shown in figure 4. The network protector of each transformer would be connected to a short bus from which the utilization devices would be supplied through air circuit breakers. These busses would be interconnected among themselves throughout the factory by means of twin cables so as to form the network as indicated in figure 3.

The cardinal principle of the 120/208-volt network system is that secondary faults are burnt clear by the fault current. Experience has shown that while this is entirely desirable and feasible with the low voltages and heavy amperages used in metropolitan distribution, it must be modified for application to factory distribution. At 440 volts secondary faults are not self clearing and it becomes necessary to use protective fuses or limiters at each end of each secondary conductor to definitely clear faults and limit the damage to that section of cable.

With the arrangement proposed it will be seen that an electrical fault anywhere in the plant will leave the major operations undisturbed. The failure of a consuming device will be cleared by its own breaker. A fault on one of the cables forming the network, for instance at X, will cause the limiters or fuses a and b to blow to isolate the fault. These are the only two limiters to carry the full-fault

current and they will, therefore, clear before any other limiter opens. A failure of the transformer or of the primary feeder, for instance at *Z*, will cause the primary breaker associated with the feeder or transformer to open and also all the network protectors on that feeder. Since the network is designed so that there must be no interruption of service with one primary feeder out of commission, this means that with two feeders the spare transformer capacity would be 100 per cent; with three feeders the spare capacity would be 50 per cent; with four feeders the spare capacity would be 33.3 per cent, and so on. With two feeders the amount of spare capacity is so great as to become uneconomical. Therefore, it is preferable to use a manual throw-over primary switch on each network transformer as indicated in figure 3.

There is a practical limit to the saving in transformer spare capacity by increasing the number of primary feeders, because with increasing number of feeders it becomes impossible to get uniform load division among the transformers left in service when one feeder is out. Also, when more than six feeders are used it is frequently necessary to consider that two feeders may be out of service at once; consequently, seven or eight feeders may require more transformer capacity than four or five feeders. For very large plants this is a very practical consideration and it may dictate the use of two networks in preference to a single network.

The quality of service, that is, reliability and voltage regulation, rendered by the secondary network is better than that provided by any other a-c distribution system. Whether the network is economical in a particular case depends on the degree of reliability required, the amount of flexibility required to meet load growth or change, and the load density and total load to be served.

Whenever it is necessary to provide greater reliability than can be obtained from a simple radial system the network will always be economical, particularly for relatively large loads. To get improved reliability in a radial distribution system it is necessary to use duplicate feeders, manual or automatic throw-over switches or breaker, load-transfer switches, sectionalizing switches or fuses, or other schemes for reducing the duration of outages. For faults on a primary feeder or in a transformer even these special radial schemes do no more than reduce the duration of the outage to a momentary interruption of service, which in many factories may not be permissible. Faults in main secondary circuits will interrupt service to all the load on that circuit until the fault can be repaired. The secondary network eliminates outages due to primary faults and most secondary faults will not interrupt service to any load. The switching equipment required in either manual or automatic radial schemes to provide duplicate power supply is expensive.

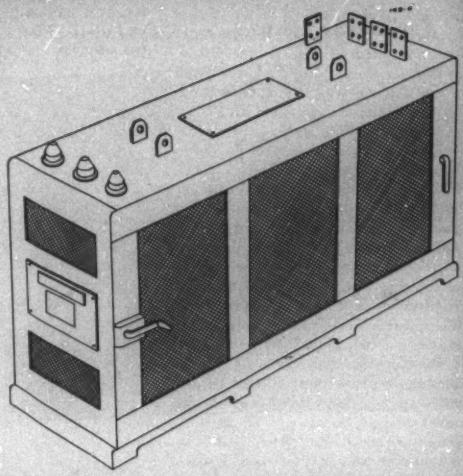


Figure 4. Three-phase indoor air-cooled network unit—transformer, primary switch, and network protector

The flexibility of the secondary network is an economic advantage. Changes to provide for load growth or changes of load concentration from one part of a plant to another usually can be made by simply installing or moving transformers to meet new load conditions. In the radial scheme any changes in load may necessitate not only changing the transformer capacity but also changing a considerable amount of secondary circuits. Since changes in processes and machines frequently are made in industrial plants, this characteristic of the network system will represent a large saving in many cases.

A comparison of the initial cost of a radial system and of a network system was made for the factory shown in figure 3. In the case of the radial system of distribution a small substation was provided at the upper end of the property comprising a transformer bank of four single-phase units of 833 kva each and primary switchgear consisting of two 500,000-kva, 15-kv oil-circuit breakers with necessary control panels. On the secondary side of the transformer bank a breaker was installed in the leads between the transformer and the 440-volt secondary bus. Five 440-volt radial feeders supply distributing points suitably located in the factory buildings.

In the case of the network system of distribution the primary 13,200-volt cables are brought to the six 440-volt network transformers of 450-kva each. Normally three transformers are connected to one cable and three to the other. In case of a fault on one primary cable the three transformers on the sound cable will be overloaded for the short period of time necessary to operate the primary switches to remove the three transformers from the fault cable and put them onto the sound cable.

With this layout it was found that the network system of distribution showed a saving of approximately 20 per cent over the radial system. It should be noted that in both systems primary circuit breakers were included at the point where the primary cables enter the property. With the network system where a group of primary feeders supply one or more industrial plant networks, it is questionable if these primary breakers are necessary in view of experience with power supply to large commercial buildings from metropolitan secondary networks. The omission of these primary circuit breakers on factory network systems would materially further lower the investment required for the network system as compared to the comparable radial system.

An Electron Microscope for Practical Laboratory Service

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DIRECT observation of extremely minute objects is of great value to both science and industry. Consequently a great deal of time and effort has been spent developing and perfecting optical instruments for making such observations. The modern light microscope is capable of rendering visible detail which is as fine as 0.00002 centimeter. Since the limit of resolving power of the normal eye is between 0.01 and 0.02 centimeter, the maximum useful magnification with these instruments is 1,000 to 2,000 diameters. Where ultraviolet light is used, the useful magnification can be increased to about 3,000 diameters.

The limits discussed above are not due to imperfections in the optical systems or lenses, but are fundamental in nature. It has been shown quite generally that diffraction effects at the object determine the least separation between points or lines on the object which can be resolved. On the basis of this limitation, the resolving power (for lines) at the object is given by

$$d = \frac{0.5\,\lambda}{\mu \sin \alpha}$$

where λ is the wave length of the radiation illuminating the object; μ the index of refraction of the medium in which the object is imbedded, and α the half angle of the cone of light entering the optical system. For visible light the smallest wave length is about 4,000 angstrom units, and the maximum index for the fluid immersing the object is 1.7; therefore, since $\sin \alpha$ cannot be greater than unity, the minimum distinguishable distance is seen to be about 1,200 angstrom units.

From the foregoing it is evident that to extend the range of observation, it is necessary either to find an immersion substance which has a very much greater index of refraction, or to illuminate the object with rays having a much shorter wave length. No known optical medium has an index of refraction greater than two or three, and no liquid suitable for use with an immersion objective has an index greater than the figure used above, namely, 1.7. Therefore, there is little hope of achieving high resolution in this direction. Electromagnetic radiation in the form of X rays and gamma rays has a wave length much shorter than that of visible and ultraviolet light used at present in microscopy. However, due to the fact that lenses or reflectors cannot be made for this portion of the spectrum, advances in this direction are also barred.

For many years the problem of observing appreciably finer detail appeared to be incapable of solution. The search, however, had been restricted almost entirely to the realm of optics, whereas actually the solution lay in an entirely different field—electronics. A little less than 15 years ago it was found that the path of electrons in electric and magnetic fields could be described in terms which are analytically equivalent to those of optics. By means of this electron optical equivalence, it was shown that axially symmetric electric or magnetic fields had the properties of optical lenses, and, consequently, that it is possible to form electron images in the same way that light images can be formed.

At about the same time, the discovery was made that any material particle in motion had associated with it a characteristic wave length. For electrons this wave length, in terms of their velocity expressed in electron volts, is given by the following relation:

$$\lambda = \sqrt{\frac{150}{V}} \text{ angstrom units}$$

On the basis of this equation, electrons moving with a velocity corresponding to 60 kv have an effective wave length of 0.05 angstrom unit, or only about 1/100,000 that of light. In other words, suitably designed electronic systems employing these high-speed electrons should be capable of extremely high resolving power.

These two concepts led directly and logically to the idea of an electron microscope based on the same principles used in an optical microscope. Such an instrument employs condenser, objective, and projection lenses, performing the same functions as the corresponding elements in the light microscope, but the lenses, instead of being made of glass, are formed by axially symmetric electric or magnetic fields. During the past 10 years, instruments of this type have been investigated in detail in various parts of the world. As a result, the electron microscope has been developed to a point where it is capable of a useful magnification nearly two orders of magnitude greater than the ordinary light microscope. Until recently, the development has been in the hands of physicists, and the instruments built were designed almost entirely for the purpose of studying the microscope itself. However, the microscope has now progressed beyond this stage, and has become a research tool of great potential value.

The problem of realizing this potential value is one for engineers, and as such, its solution was undertaken in the RCA Research Laboratories at Camden, New Jersey. Starting from the basic physical principles, it was necessary to work out the design of an instrument which would be sufficiently simple in operation and rugged in construction to be operated by the average worker in any scientific or industrial research laboratory, and would not require the supervision of a trained physicist. An RCA microscope, developed by L. Marton,[1] which fulfills in part the requirements of a generally practical microscope, was described in an earlier number of ELECTRICAL ENGINEERING.[2] This microscope, although very satisfactory from the standpoint of resolving power, proved to be somewhat difficult to operate and very critical in adjustment and alignment. Furthermore, the instrument and associated equipment occupied a large amount of space.

Work on the electron microscope was continued in order to overcome the objectionable features mentioned above. As a result, an instrument has now been developed by J. Hillier which is completely self-contained, occupies only a small amount of space, and is so simple to adjust and operate that it can be readily handled by any capable laboratory technician.[3] In addition, the microscope incorporates an improved type of magnetic objective lens which increases its resolving power for specimens supported in the manner described below.

Figure 1 is a photograph of the complete microscope. The unit includes not only the microscope itself, but also the regulated power supplies providing the 60-kv over-all voltage and the current for

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V. K. ZWORYKIN, J. HILLIER, and A. W. VANCE are all with the RCA Manufacturing Company, Inc., Camden, N. J. DOCTOR ZWORYKIN is associate director, research laboratories.

1. For all numbered references, see list at end of paper.

Figure 1. RCA electron microscope

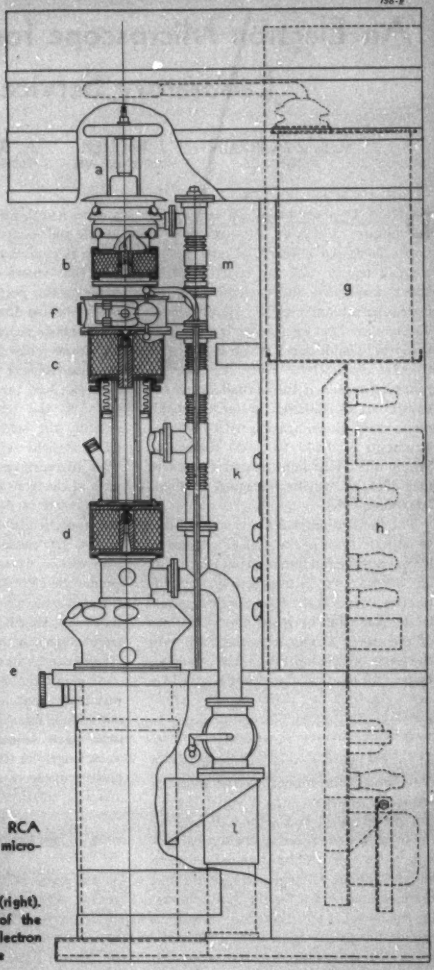


Figure 2 (right). Diagram of the RCA electron microscope

the three magnetic lens coils. The oil diffusion pump for maintaining the required vacuum within the instrument is also contained in the unit.

A simplified drawing is given in figure 2, which shows the construction of the microscope. The electrons used in the imaging process are supplied from the electron gun (*a*), containing a thermionic cathode which is maintained at 60-kv negative with respect to ground, and a final anode at ground potential. Between the two are disposed the electrodes required for governing the electron paths. The electrons leaving the gun have their full velocity, corresponding to 60 kv.

The condenser lens (*b*), which consists of an iron-clad coil with pole pieces shaped to give the required magnetic field, causes the electrons to converge upon the specimen held a few centimeters below it. The condenser, like the condenser lens of a light microscope, can be used to control the angular aperture of the illumination at the specimen.

After passing through the specimen, the electrons enter the objective lens (*c*). This lens deflects the electrons leaving the specimen in such a way as to focus them into a magnified intermediate image of the specimen. This image is formed directly above the projection lens (*d*). The objective, like the condenser, is an armored coil, but the pole pieces are, of course, different in design to meet the requirements of this element. The design of the object lens is very important, and the success or failure of an electron microscope depends to a large extent upon the skill and accuracy with which it is designed and constructed.

The final image is formed from the por-

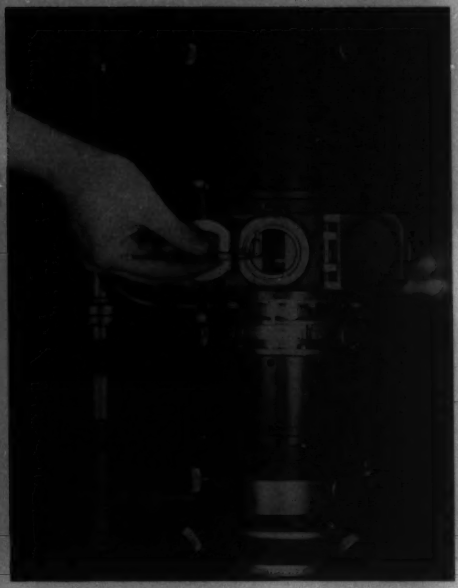


Figure 3. Air lock and object chamber

tion of the intermediate image which passes through the projection lens (*d*) and is reimaged in the plane of the observing screen or photographic plate at (*e*). The magnification of the intermediate image is about 100 diameters, and the magnification by the projection lens can be varied between 20 and 300 diameters; therefore the total magnification can be controlled over the range between 2,000 and 30,000 diameters. The maximum electronic magnification of the microscope is two or three times less than the greatest useful magnification corresponding to the resolving power of the instrument, the full useful magnification, for reasons that are discussed below, being obtained by additional photographic enlargement. When visual observation of the specimen is required, the final image is allowed to fall on a fluorescent screen. This screen can be raised out of the way to permit the image to impinge upon a photographic plate for a permanent record, or for more detailed examination.

Since electrons will not travel freely through air, the entire electron optical path of the microscope must be under vacuum, that is, at a pressure of about 10^{-5} millimeters Hg. All permanent joints are brazed or soldered so that they are vacuum-tight without the aid of sealing compounds. The demountable joints, such as those between the electron lenses and the microscope chambers, are sealed with Neoprene, and are arranged in such a way that the alignment is maintained by metal-to-metal contacts rather than by the metal-to-plastic contacts. At certain points in the microscope, parts must be movable with respect to one another in order to permit alignment. Such parts are jointed by flexible metal bellows so the adjustments may be made while the microscope is under operating conditions. No greased joints are used in the microscope.

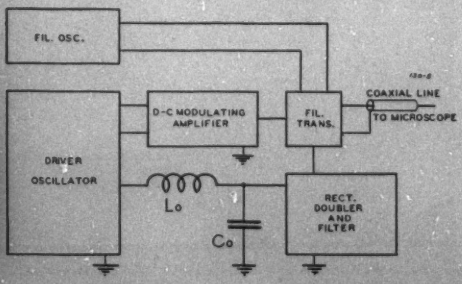
If it were necessary to repump the entire microscope every time a specimen or photographic plate is changed, it would greatly curtail the speed of operation of the instrument. Consequently air locks are provided which permit making these changes without breaking the main vacuum. The air lock for the object chamber (*e*) is shown in figure 3. A handle at the rear of the chamber raises the object from its position over the objective, moves it into the air lock, and closes the latter off from the main chamber of the microscope. A second handle admits air to the lock and opens it so that the object may be removed. When the object is replaced, the second handle closes the air lock, connects it with an auxiliary pump for a preliminary exhaust, and then seals it off. With the first handle, the specimen is moved back into the microscope to its original position.

The photographic chamber, which is shown in figure 4, is arranged with a similar air lock. The photographic plate used with the microscope is about ten by two inches in size. The long plate permits making a number of exposures on the same plate. An adjustable mask governs the width of the pictures.

The microscope pumping system con-

Figure 4. Photographic chamber

Figure 5. Block diagram of high-voltage supply



sists of a three-stage oil diffusion pump (*l*), in figure 2, which is connected to the main chamber of the instrument through the manifold (*m*). This pump is backed up by a mechanical fore pump. A second auxiliary mechanical pump is used to exhaust the two air lock chambers.

Figure 6. Rear of microscope showing power supply and regulator units

It can be shown that the focal length of a magnetic electron lens depends upon the current through the lens coil and the velocity of the electrons themselves. This means that the high-voltage supply and the lens current sources must be very free from fluctuations. In order to obtain a resolving power of 10^{-7} centimeters it is found that the following stabilities are required:

Over-all microscope voltage	0.015 per cent
Objective current	0.0075 per cent
Projection lens current	0.068 per cent
Condenser lens current	0.1 per cent

The problem of obtaining 60 kv with the required degree of constancy in the small space available is both difficult and interesting. The high-voltage supply, which was designed by A. W. Vance, employs radio-frequency power rather than the conventional 60-cycle power to actuate the step-up transformer unit.[3] This results in a number of advantages. A low-loss resonant coil can be used which occupies only a small volume and requires only a small exciting power. Much smaller condensers can be used for a given allowable amount of ripple. A regulator operating on the low-voltage side of a rectifier is limited in its speed of regulation by the frequency of the power supplied. At radio frequency, this limitation becomes unimportant. Finally, stray fields, which are difficult to shield at 60 cycles, are easily shielded when radio frequency is used. It is, therefore, possible to mount the power supply close to the microscope as an integral part of the unit.

A block diagram of the high-voltage unit is given in figure 5. The basic circuit consists essentially of a high-Q resonant net which presents series resonance to the driving oscillator, and is parallel resonant to the high-voltage output rectifiers. The resonant circuit consists of coil L_0 and the effective lumped capacity C_0, which is made up of the rectifier capacitance and stray capacities. To obtain a given output voltage, the exciting power required from the oscillator, since the load is very small, depends upon the Q of the circuit and the resonant impedance of the high-voltage coil. Great care must be used in the design of the coil and in the selection of operating frequency in order to obtain a high Q and maximum impedance. The actual frequency selected is 32 kilocycles, and the Q of the resonant circuit is about 200. The exciting power required to produce the desired power is about 150 watts, and the maximum load in the neighborhood of 30 watts.

Since the Q of the resonant circuit is high, the driving frequency from the oscillator must be exactly correct if large inefficiencies are to be avoided. In order to maintain the correct driving frequency, the frequency oscillator is controlled by the resonant circuit itself. The output voltage of the power supply is governed by the amplitude of the current from the oscillator. This, in turn, is varied by the screen-grid voltage applied to the oscillator output tubes. By controlling the screen voltage, not only can the output voltage be set at any desired value, but also the constancy of the voltage can be governed.

The rectifier across the resonant circuit is arranged to give voltage doubling. The type of doubler used permits grounding one side of the high-voltage coil, thus permitting the use of a simple resonant circuit rather than a tuned transformer.

Figure 7. Preparation of supporting films for specimens

Figure 8. Micrograph of pseudomonas aeruginosa bacteria. Magnification 14,000 diameters

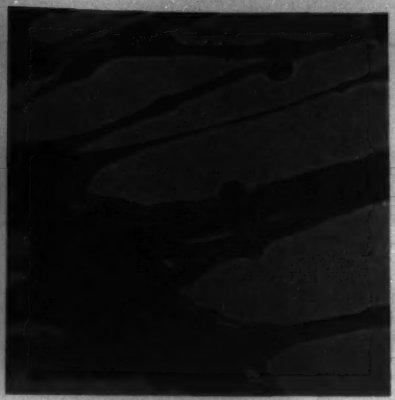


Figure 9. Micrograph of slightly polymerized vinyl chloride. Magnification 77,000 diameters

Figure 10 (right). Micrograph of polymerized vinyl chloride. Magnification 100,000 diameters

The high-frequency ripple is eliminated from the high-voltage output by means of a tuned filter. Low-frequency disturbances are removed by comparing a fraction of the output voltage obtained from a special divider with a standard voltage,[4] and controlling the oscillator screens by means of a d-c amplifier. Such a feedback regulator, when certain necessary precautions are effected, is capable of extreme constancy. The measured voltage fluctuation over a period of 30 minutes is less than 0.002 per cent in the actual microscope power supply.

The current supplies for the three lens coils are controlled by very sensitive regulators. These regulators make use of well-known principles, and will not be discussed here.[4] By careful design and the use of a number of special refinements, these current sources have a constancy of better than 0.002 per cent for the objective lens, 0.004 per cent for the projection lens, and 0.02 per cent for the condenser lens.

The complete power supply is assembled in a cabinet which forms the back part of the microscope unit. The lens current sources and the oscillators are located at (*e*) in figure 2. The high-voltage coil, rectifiers, and filters are immersed in the oil tank (*f*). Short, corona-proof leads carry the high voltage to the gun of the microscope. All power supplies are completely interlocked to insure absolute safety, and protective relays are arranged to open the high-voltage circuit in event that vacuum conditions within the microscope are not right. Figure 6 is a photograph of the rear of the instrument with the door to the power-supply section open so that the general arrangement of the equipment can be seen.

The operation of the instrument is simple in the extreme. The operator seated in the observers' position can reach the electrical controls and thus adjust overall voltage, magnification, or focus, while watching the image. In addition, the specimen can be moved in two directions in a horizontal plane, so that any portion of the object may be brought into the field of the microscope. Six ports are provided for viewing the final image, and, in order to permit initial orientation of the specimen, three small windows allow direct observation of the intermediate image.

To record the image photographically, it is only necessary to move the plate into position under the fluorescent screen, and then to raise the screen so that the electron image falls on the plate. The fluorescent screen is designed to serve as the shutter for timing the exposure. It is expedient when making electron micrographs to use as low an electronic magnification as possible, and to obtain the

Figure 11. Micrograph of commercial chemical. Magnification 150,000 diameters

Displacement and Diffusion in Fluid-Flow Arc Extinction

JOSEPH SLEPIAN
FELLOW AIEE

Synopsis: The displacement and diffusion theories of arc extinction in flowing fluids are defined and contrasted. The question as to the possibility according to hydrodynamical principles of the formation of the wedge required by the displacement theory is considered and decided in the negative. Photographic evidence is also found to contradict the displacement theory. How turbulence will multiply diffusive effects is considered, and an estimate of 100fold multiplication is given for conditions existing in gas blast breakers. This enhancement of diffusion by turbulence is found to make the diffusion theory adequate for accounting for the circuit interrupting capacities of arcs in gas blast circuit breakers.

I. Introduction

THE important large effect which motion of the circumambient fluid has upon the circuit interrupting ability of an a-c arc has long been known, but there are still widely diverging theories as to how this effect comes about. Slepian,[1] in discussing the influence of gas motion in self-generating gas blast devices such as oil circuit breakers and expulsion fuses stressed the effect of turbulence in causing a more rapid mixing of hot and cold gas volumes, thus speeding the spread of heat, and a more rapid mixing of highly ionized with unionized gas volumes, thus speeding the dilution of the ions into larger volumes. The theory here, then seems to have been that the function of the gas motion is to intensify or enhance diffusive effects, and more particularly, thermal conduction and ion diffusion. This type of theory which makes the powerful arc extinguishing effect of the fluid flow depend entirely upon its creating conditions where diffusive effects are greatly enhanced shall be called in this paper the "diffusion theory".

A radically different theory of the extinguishing effect of the fluid flow was advocated by Prince,[2,3] which shall be called in this paper the "displacement theory". This theory states that at current zero (or perhaps at a moment very near to current zero), the physical continuity of the arc is broken at some obvious geometrical point, by the interposition of a small quantity of *cool, un-ionized,* and *dielectrically completely sound* fluid. From this moment on, the dielectric strength of the arc space is completely given by the dielectric strength of this interposed fluid. The relative velocity of the two ends of this interposed fluid is believed to be one or sometimes two times the mean velocity of the fluid in that neighborhood. Thus the thickness of the interposed fluid grows rapidly, being given by the product, vt, of the fluid velocity and the time. The rate of growth of the total dielectric strength of this interposed fluid in volts per second, will be given by Xv, where X is the intrinsic dielectric strength of the interposed fluid in volts per centimeter, and v is the fluid velocity in centimeters per second. Arc extinction thus is said to depend on whether or not this rate of recovery of dielectric strength of the interposed fluid exceeds the so-called "recovery rate" of the circuit. That is the arc will be extinguished if

$$Xv > \frac{dV}{dt}$$

where $\frac{dV}{dt}$ is the circuit "recovery rate" in volts per second.

Apart from whether the "displacement theory" is correct or not, it has the incontestable advantage that it leads directly to an attractively simple equation, so that the designer or user of a circuit breaker who accepts this theory may have the comforting assurance that the breaker performance has been "calculated". Hap-

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1. For all numbered references, see list at end of paper.

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full useful magnification by photographic enlargement of the plates. In general, a photographic enlargement of six to ten times can be made without bringing out the grain of the emulsion. Therefore, if the total useful magnification required is 100,000 diameters, the electronic magnification will be 10,000 to 16,000. The advantages of this procedure are that it decreases the exposure time, reduces the bombardment to which the object must be submitted, and increases the useful field of view of the microscope.

The specimens themselves are mounted somewhat differently from those used with a light microscope. Glass slides would be completely opaque to electrons; therefore the objects to be examined are mounted on extremely thin cellulose films, supported by a fine wire mesh. The method of preparing one of these supporting films, which are only about 0.000001-centimeter thick, is illustrated in figure 7. The material or particles to be studied are usually suspended in water or some other suitable liquid, and a drop of the suspension is placed on the film. After the liquid has evaporated, the specimen is ready for use.

The utility of this instrument is almost unlimited, and it finds applications in many fields of scientific and industrial research. Two fields, chosen at random, serve to illustrate its value. In bacteriology and biology it opens up new and entirely unexplored realms, for with this microscope microorganisms such as viruses, which cannot even be seen with an optical instrument, can be studied in detail. Figure 8 is a typical micrograph of pseudomonas aeruginosa bacteria. Much of the structure seen in this photograph is well below the resolving power of an ordinary microscope. In physical chemistry it can be used to study colloids, point reactions, the structure of thin films, and even large organic molecules. To illustrate this application, micrographs of slightly polymerized and polymerized vinyl chloride films are shown in figures 9 and 10. The final photograph illustrates a commercial chemical product. Structure of less than 50 angstrom units can be resolved in this micrograph.

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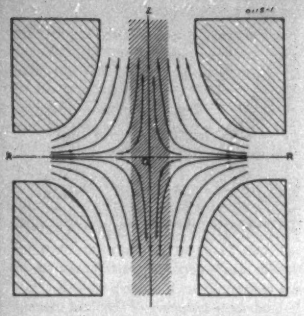


Figure 1. Ideal flow in a double nozzle

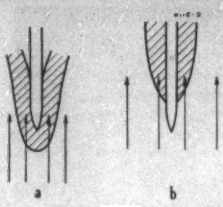


Figure 2 (left). Wedge formation at sharp splitter in ideal fluid

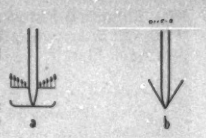


Figure 3. Bending of an arc around a gas-forming splitter

pily, however, designers of breakers "calculated" in this way have not dispensed with thoroughgoing high power laboratory tests, so that the performance of such breakers rests on a more solid foundation than the "calculation".

European investigators have advocated both the diffusion and displacement theories. O. Mayr[4] quite definitely makes diffusive effects the dominating factor in determining arc extinction, but Kesselring and Koppelmann[5] principally because they are not able to calculate a sufficiently large interrupting effect on the basis of diffusion, espouse the displacement theory. However, in their calculations which at best can only be regarded as giving orders of magnitude, because of the uncertainty of our present knowledge of the fundamental processes going on in the rapidly changing arc, Kesselring and Koppelmann underestimate completely the great enhancement of diffusive effects arising from even only a moderate degree of turbulence.

Holm, Kirschstein, and Koppelmann[6] speak of the effect of gas motion and its turbulence in increasing the thermal losses from the arc during the current conduction period, but do not take into account the effect of turbulence in increasing ion loss by enhanced diffusion. Also, surprisingly, although they seem to recognize the importance of turbulence during the conduction period, in the "currentless pause" (stromlose pause) near current zero they use for the thermal conductivity and ion diffusion coefficient numbers appropriate to a gas at rest, and overlook the great increase in these quantities arising from the gas motion. Thus they greatly underestimate the voltage interrupting capacity of an arc of small section at current zero.

These last authors also speak of the possibility of a cutting of the physical continuity of the arc, but state at once that such cutting cannot happen, *loc. cit.*, page 84, but that rather a configuration favorable for rapid diffusion occurs where one might naively suggest a cutting. With this exception, none of the references just mentioned question whether accepted hydrodynamical principles will permit the formation of a growing wedge of sound fluid interrupting the continuity of the arc.

II. Impossibility of Wedge Formation in Interior of Ideal Fluid—Diffusion Absent

To see clearly why hydrodynamical principles forbid the formation of an interrupting wedge, consider the flow of an ideal fluid pictured in figure 1. This portrays a flow corresponding to the double nozzle discussed by Kesselring and Koppelmann. We choose an ideal fluid, that is, one with zero viscosity, because we wish to exclude diffusion effects, and viscosity is a consequence of diffusion, namely the lateral diffusion of molecules from faster moving regions into slower moving regions, and vice versa. For simplicity in calculations let us assume the fluid incompressible. A little thought soon convinces one that compressibility does not alter the conclusions reached.

In figure 1 we have fluid flowing inward radially through a circumferential opening, and axially out along the Z axes through a double nozzle. At the time $t=0$, we fix our attention upon the column of fluid shown shaded, which might be the arc configuration near current zero. However, to keep the flow considered simple, let us assume that the shaded column of fluid has the same density as the rest of the fluid, and not a much lower density as in the high temperature arc. We may perhaps regard the shaded column of fluid marked with a non-diffusing ink giving a negligible density change in the fluid.

One might imagine from inspection of the figure, that as the flow proceeds, the shaded column would be broken or cut in two, and that presently the two newly formed ends would be receding from each other with twice the axial fluid velocity through the nozzles. However, a little calculation shows that this is not at all the case. In the neighborhood, O, of the geometrical center of the figure, the axial velocity is given by

$$v_z = Az \tag{1}$$

where z is the distance along the axis from O, and A is a constant, and the radial velocity, is given by

$$v_r = \frac{dr}{dt} = -\frac{1}{2}Ar \tag{2}$$

where r is the distance from the central axis. These equations will hold approximately out to distances approaching the nozzle dimensions.

The bounding cylindrical surface of the shaded region will be described by the equation,

$$r = r_0 \tag{3}$$

at $t=0$.

The subsequent motion of this bounding surface will be obtained by integrating equation 2. We obtain at once,

$$r = r_0 e^{-1/2 At} \tag{4}$$

The cylindrical surface remains cylindrical, but its radius approaches zero at a constantly diminishing rate. There is no formation of a surface with two nappes; no interrupting wedge appears. The length of this cylindrical column of constantly diminishing radius will be comparable with the nozzle dimensions.

To get some quantitative ideas of the rate of thinning of the cylindrical column, let the axial velocity of the fluid be $3 \cdot 10^4$ centimeters per second at 1 centimeter from O then $A = 3 \cdot 10^4$. Then equation 4 becomes

$$r = r_0 e^{-\frac{t}{66.7 \times 10^{-6}}} = r_0 2^{-\frac{t}{45.2 \times 10^{-6}}} \tag{5}$$

We see that the column has its radius halved each 45.2 microseconds, but the radius never becomes actually zero.

If we assume no diffusion takes place, the density of the ink marking the thinning column remains unchanged. Applying the ideas developed here to the arc, we see that pure streaming, without diffusive effects, will thin the arc, but will not change its temperature or ion density, and therefore will not change its dielectric strength per unit length.

III. Enhanced Diffusion Responsible for Interrupting Effectiveness of Axial Flow

The preceding section has made clear that without diffusion (of which thermal conductivity and viscosity are consequences), axial streaming of the fluid as in a double nozzle can have no interrupting effect upon the alternating current arc near current zero. All it can do is to cause the radius of the arc stream to shrink asymptotically to zero, with no change in ion density or temperature of the arc space.

However, it is evident that this effect of the motion of the fluid in reducing the arc diameter can play an important part in increasing greatly the interrupting effect of such diffusive forces as are intrinsically present. The time constant for diffusion from a cylindrical region, that is, for example the time for the ion density to be reduced to one-half, or the time for the temperature to fall to one-half, varies as the square of cylinder diameter. Thus, in the numerical example given in the preceding section, the rate of ion loss, and the rate of cooling will multiply by 4 every 45.2 microseconds, during the interrupting period, due to the reducing arc diameter.

However, this is far from the whole story. As Kesselring and Koppelmann[6] have shown, taking the small arc diameters such as are actually observed at current zero in the double nozzle flow, ordinary diffusion and thermal conduction are still not great enough to account for the observed interrupting effect. The high interrupting capacity comes because there is inevitably a high degree of turbulence in the axial flow through the arc.

In the example discussed in the preceding section and pictured in figure 1, the velocity in the incompressible ideal fluid varies in space according to equations 1 and 2. By Bernouilli's principle, the pressure in the fluid will vary in space according to the equation

$$p_0 = p + \frac{1}{2}\rho(v_y^2 + v_z^2) \qquad (6)$$

where p_0 is the pressure at 0, the point of zero velocity. At each point, the velocity is determined by the fall in pressure to that point, but it should be observed that for a given pressure distribution, the velocity will vary inversely with the square root of the density of the fluid.

But now suppose that the shaded cylinder of figure 1, instead of having the same density as the rest of the fluid, has a density, like that of an arc, only $^1/_{20}$ or less, of the density of the surrounding fluid. The pressure distribution must remain continuous. Hence at any particular distance from O, the velocity in the arc would need to be $\sqrt{20}$ or more times the velocity of the adjacent cool and more dense fluid. There would have to be then a sharp discontinuity in fluid velocity, and enormous shearing stresses at the arc boundary due to viscosity. What happens under such conditions is that the smooth streamline flow portrayed in figure 1, is replaced by an intensely turbulent flow through the arc, the kinetic energy of the turbulence adding itself to the kinetic energy of the average motion to give a total velocity head compatible with Bernouilli's equation 6.

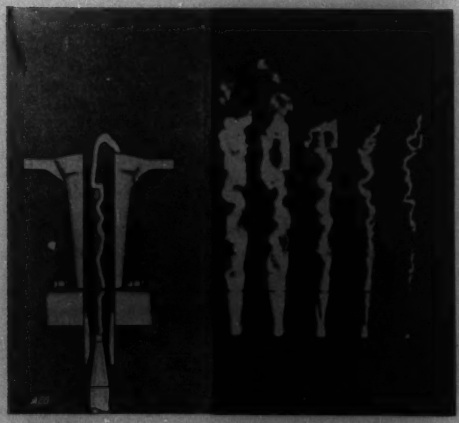
As we shall see in section VI, this high degree of turbulence functions to further greatly increase the rate of cooling and deionization of the arc stream at current zero, and probably fully accounts for large interrupting capacity of the axial flow.

IV. The Cross Blast—Wedge Formation at a Splitter

Compressed air circuit breakers have been recently introduced[7] in which the arc is blown transversely against several splitters made of gas forming material. Let us examine what may happen to an arc column at such a sharp splitter.

Under the influence of the fluid motion, the arc is lapped round the sharp splitter in a thin column as current zero is approached as in figure 2*a*. What does the further motion of the fluid do to this column? Photographic records show that the thickness of this column is too great for simple diffusion or thermal conductivity to account for the high interrupting capacity actually found. Does the moving fluid cause the column to be cut, and introduce between the cut ends a longer and longer path through good dielectric? Or does the fluid motion so enhance diffusive effects that even the relatively thick long column cools and deionizes quickly enough to have a high interrupting capacity?

If the fluid is ideal, with zero viscosity (and therefore also with zero thermal conductivity and zero ion diffusion), the answer is certainly that the arc column is cut as in figure 2*b*, with the recovered dielectric strength equal to that of the path through the introduced fluid between the cut ends of the arc column. The displacement theory then will apply. But



Lichtbogen vor dem Erlöschen
Gleiche Aufnahme, welcher kopiert.
Fortgesetzte Emission von Ladungsträgern
aus der glühenden Elektrode

Figures 4 (left) and 5 (right). High-speed motion pictures by Biermanns

Figure 6. Arc against splitter, by Prince

Figure 7. Arc against splitter, $16^2/_3$ microseconds after figure 6

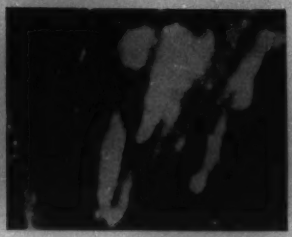


Figure 8. Arc against splitter, $16^2/_3$ microseconds after figure 7

the fluid will need to flow with its full velocity parallel to and right up to the splitter wall.

However, actual fluids cannot flow in this manner. Even with very small viscosity, the fluid velocity next to the splitter wall must be zero. Otherwise infinite shearing stresses would be exerted on the fluid and wall. A layer is formed next to the splitter wall, in which the fluid velocity varies from zero at the wall, to the full streaming velocity away from the wall. In this boundary layer, the shearing stresses arising from viscosity are large compared with the inertial forces.

With homogeneous fluid, the boundary layer starts with zero thickness at the splitter edge, and grows in thickness upstream from the edge. In this first part of the boundary layer, the flow is laminar, but at some point far enough upstream the flow in the boundary layer becomes turbulent, and the boundary layer thickness then increases more rapidly.

For air, at high velocity, and with a well designed splitter, such as an air-foil, the boundary layer a few centimeters upstream is only a few thousandths or a hundredth of a centimeter thick. We might imagine then that figure 2 could be corrected by drawing such a thin boundary layer joining the two receding ends of the cut column. Since so thin a boundary layer would cool and deionize exceedingly rapidly, this correction would not seriously change the conclusions of the displacement theory.

However, in the actual circuit breaker, we do not have a homogeneous fluid flowing past the splitter, but the density of the arc column is only one-twentieth that of the flowing air. We may expect then that the boundary layer will start in a turbulent state from the very beginning at the splitter edge. Still further complicating the situation is that under the heat of the arc, the splitter material gives off gas at a high rate, this gas evolution continuing right through current zero. This gas projected out from the wall will certainly widen the boundary layer enormously, and make it wide even at the beginning of the splitter. But with a wide boundary layer, the displacement theory fails completely since a wedge of fresh fluid interrupting the arc growing with the full streaming velocity of the fluid cannot form. The arrows in figure 3*a* are intended to show by their length the mean velocity distribution in the boundary layer. We fix our attention on the horizontal line just touching the splitter edge, and which we suppose moves with the fluid. This line may represent a bounding surface of an arc column near current zero. A finite time later the line will look as in figure 3*b*. Because of the zero velocity at the splitter surface, the line is bent, but not cut.

V. Photographic Evidence Concerning Displacement Versus Enhanced Diffusion

High-speed motion pictures taken of arcs being extinguished in axial and cross blasts offer valuable evidence for determining whether the displacement or enhanced diffusion theory is correct. J. Biermanns[8] shows pictures taken at 5,000 per second of an arc blown through a single nozzle. Figures 4 and 5 are examples taken from Biermanns' paper. Extinction seems to have taken place after the fourth picture in figure 5. If the displacement theory were correct we would expect to see in the fifth picture a completely dark break in the continuity of the luminous arc, and this break should be at most $200 \cdot 10^{-6}$ second, the time interval between pictures, multiplied by the probable velocity, about $3 \cdot 10^6$ cm, or about 6 cm. Actually, in the fifth picture of the lower half of figure 6, there is a length of about this magnitude which is darker than the rest, but it is not completely dark, and also there are in it several splotches which are more intensely luminous. If this darker length does represent the growing wedge introduced into the arc according to the displacement theory, we must conclude that this wedge far from being fresh dielectrically sound fluid, is considerably contaminated by inmixing of ionized and radiating gas from the arc itself. This contamination, which is evidence of considerable turbulence, should be extremely great when the wedge is short, thus making it impossible to speak at all of a short wedge of nearly fresh dielectrically sound fluid. It is only after the "wedge" is of considerable length that it can have decontaminated itself so that it can be regarded as being of dielectrically sound material. This decontamination, however, according to section II can proceed only from diffusion, so that we are driven inevitably to the diffusion theory according to which a considerable length of the arc column finds itself in a condition so favorable for rapid diffusion that it recovers dielectric strength sufficiently rapidly to effect circuit interruption.

Comparison of the upper part of figure 5 with the lower which was obtained from a photographic print with much less contrast, also gives evidence of diffusion much intensified by turbulence. The sharply defined intensely luminous arc column in upper figure 5 is revealed in lower figure 5 as surrounded by less luminous gas which must have diffused rapidly out of the arc column.

Prince[7] has shown some extraordinary pictures taken at 60,000 per second of a circuit interruption by an arc in a cross air blast against fiber splitters. Three of these successive pictures, which are believed by the present author to include the moment of circuit interruption are reproduced here as figures 6, 7, and 8. In figure 6, the arrows introduced by this author point out the two-inch length of arc which he believes to have been responsible for the circuit interruption. This length of arc lies squeezed up against the splitter surface. At the splitter surface itself, the mean velocity of the gas

in the arc parallel to the surface must be zero. At the other boundary of the arc, the non-luminous air is moving with very high, probably acoustic velocity. The velocity gradient is then very large in this arc. Also, there is a very sharp change in gas density at the boundary of the arc. Lastly, gas from the decomposing splitter is being projected perpendicularly into the arc column. All these factors must create an intense turbulence, which must so enhance diffusion that these two inches of arc are cooled and deionized extraordinarily rapidly.

In any case, figure 7 shows that after only $16^1/_2$ microseconds the two inches have lost most of their luminosity, and in figure 8, after another $16^1/_2$ microseconds the luminosity has almost completely disappeared. If we assume acoustic velocity of $3 \cdot 10^4$ cm per second, the fluid displacement in $16^1/_2$ microseconds would be only $^1/_2$ cm. This is very small compared to the two-inch length of arc column which seems to be the first less luminous break to make its appearance in the succession of pictures. Thus these high speed pictures of Prince support strongly the enhanced diffusion theory as against the displacement theory.

VI. Turbulence and Enhanced Diffusion

Appreciation of the fact that fluid motion enhances diffusion is as widespread as the custom of accelerating the sweetening of coffee by stirring with a spoon. Recent developments in the theory of turbulence, however, now make it possible to give a rough numerical measure to this degree of enhancement.

When a sufficiently small dimensioned measuring instrument is used, the velocity at a given point in a steadily streaming fluid is found to be not constant, but to have very rapid variations in magnitude of an apparently random character. Thus figure 9 shows the velocity reading obtained by Dryden[9] in a wind tunnel with a hot wire anemometer made of Wollaston wire, 0.008 mm (0.0003 in.) in diameter. This rapidly varying deviation, u, from the mean velocity U is called the turbulent velocity, and its root mean square with respect to time, $\sqrt{\overline{u^2}}$, is called the intensity of the turbulence. The ratio of the turbulence intensity to the mean velocity in figure 9, according to Dryden is as much as nearly 0.01, even in a wind tunnel where every effort is made to eliminate turbulence as far as possible. In the cases discussed in the previous section the ratio of the turbulence intensity to the mean velocity

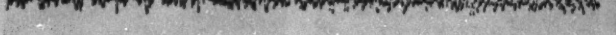


Figure 9. Turbulence in a wind tunnel, by Dryden

Turbulence of wind tunnel, $\sqrt{\overline{u^2}}/U = 0.0085$. Time = 0.4 second approximately. Relative amplification = 64

must be very much greater. One, or an even greater number, would seem to be a not unreasonable figure for this ratio. We may then certainly take 10,000 cm per second as a conservative estimate of the intensity of turbulence in the arc columns placed in rapidly streaming fluids in the examples discussed in the previous sections.

The turbulence may perhaps be pictured as a large number of small eddies or vortices superimposed on the average smooth motion of the fluid. These eddies are of constantly changing size, and velocities, but in a steady state of flow show a statistical constancy. To reveal the turbulent motion, the velocity measuring instrument must have dimensions small compared to the geometrical dimensions of the individual eddies.

This picture suggests how turbulence may bring about diffusion. A very small portion of the fluid upon which we fix our attention, takes part in the motion of an eddy. A moment later, however, it is part of another eddy, having a different center. It can thus wander from eddy to eddy, off the average flow lines of the fluid. But such motion we call diffusion.

A great similarity will be noted between this picture, and the picture of diffusion in a stationary gas offered by the kinetic theory of gases. According to this kinetic theory, even for a gas at rest, the individual molecules have velocities which are random in direction and magnitude. The mean random speed, c, of the molecules is of the order of acoustic velocity of the gas, or for normal air $3 \cdot 10^4$ cm per second.

The motion of a molecule moving in any particular direction will be arrested and changed into other random directions by collisions with other molecules. Thus the individual molecule will wander about in space in a random manner. This random wandering is molecular diffusion.

The speed with which a particular molecule wanders away from any particular fixed point in space will depend on the average absolute speed of the molecule, c, but it will also depend on the average distance the molecule goes before making a collision which changes the direction of its motion, that is the mean free path λ. The diffusion coefficient for the molecule, according to elementary kinetic theory is given by

$$D_m = \frac{1}{3} c\lambda \tag{7}$$

In looking for an analogous expression to estimate the diffusion coefficient arising from turbulence, we already have a factor which would seem to correspond to the molecular speed, c, namely the turbulence intensity $\sqrt{\overline{u^2}}$. What will correspond to the mean free path λ? Most plausibly, the average eddy size!

G. I. Taylor[10] has recently shown how from measurements of the turbulent velocity, u, a length may be determined of just this character. Taylor considered the correlation coefficient between the turbulent velocities, u_1 and u_2 at two nearby points in the moving fluid. The correlation coefficient is defined as

$$R = \frac{\overline{u_1 u_2}}{\sqrt{\overline{u_1^2}}\sqrt{\overline{u_2^2}}} \tag{8}$$

The dashes above the functions of time in equation 8 signify that the average with respect to time of the functions must be taken.

It may be shown mathematically that if two functions u_1, u_2, have a correlation coefficient R equal to unity, then the two functions must be completely identical in form, that is $u_1 = ku_2$, where k is a constant. On the other hand, if the two functions are completely unrelated, then u_1 is as likely at any moment to differ in algebraic sign from u_2 as to agree with it, and $\overline{u_1 u_2}$ and therefore R will be zero.

If the two points, 1, 2, being considered stayed always on the same eddy, then $u_1 = ku_2$, and $R = 1$. On the other hand if the points 1, 2, are always on different eddies, then u_1 and u_2 are completely unrelated, and the correlation will be zero, $R = 0$. The actual correlation R for two points, which will generally have a value between 1 and 0, may be regarded as measuring the fraction of the time the two points are on the same eddy.

The correlation coefficient may be directly measured by the use of appropriate electrical circuits used in conjunction with very fine hot wire anemometers. Figure 10 shows the correlation coefficient obtained by Dryden[9] as a function of distance of the second point from the first in turbulence produced in a wind tunnel by screens of different mesh sizes. As might be expected when the two points are very close together, the correlation

coefficient is unity, and when they are far apart it is zero. The distance in which the correlation coefficient drops to zero gives a measure of the average eddy size.

Taylor[10] defined a turbulence scale factor

$$L = \int_0^\infty R ds \qquad (9)$$

where s is the separation of the two points. L may be regarded as the average eddy size, and should be the analogy of the mean free path λ, in the kinetic theory of molecular diffusion. From figure 10, we see that in the turbulence measured by Dryden, the scale factor is of the same order of magnitude as the mesh sizes of the screens producing the turbulences.

Leaning on the analogy with the kinetic theory of molecular diffusion in gases at rest, and referring to equation 7, we arrive at the strong expectation that the effective diffusion coefficient, D_t due to the turbulence should be given by

$$D_t = B\sqrt{\overline{u^2}}\, L \qquad (10)$$

where B is a constant not very small compared to unity. The ratio of D_t to D_m may then be expected to be of the order of $\sqrt{\overline{u^2}}L/c\,\lambda$. We have just seen that c is of the order of acoustic velocity, and that in practical gas blast circuit breakers $\sqrt{\overline{u^2}}$ is also of the order of 10^4 cm/second λ, under normal gas conditions is of the order of 10^{-5} cm. What magnitude shall be taken for L?

Referring again to figure 10, which shows that the turbulence scale factor has about the same magnitude as the scale of the physical structure responsible for the turbulence we are led to expect that in the gas blast circuit breaker, L, will be about the same as the dimension of the arc section. Near current zero, in the axial flow breaker, this is about 10^{-1} cm, and for the cross blast breaker, with gas forming splitters, it is considerably larger. We find, then, with respect to order of magnitude,

$$D_t/D_m = B\sqrt{\overline{u^2}}L/{}^1\!/_3 c\lambda$$
$$= 10^4 \cdot 10^{-1}/10^4 \cdot 10^{-5} = 10^4 \qquad (11)$$

Thus we see that under the conditions occurring in gas blast breakers the intense turbulence brings about an enormous multiplication of the effective diffusion coefficient. Even allowing for all the looseness in dealing only with orders of magnitude, we see that a 100fold enhancement of diffusion effects is not an unreasonable expectation.

This means that all the factors contributing to arc extinction, such as ion diffusion and cooling by thermal conduction are also multiplied 100fold. The difficulty then which Kesselring and Koppelmann[4] experience in adequately accounting for the interrupting capacity on the basis of diffusive effects alone, disappears.

VII. Summary

1. The displacement and diffusion theories of a-c arc extinction in rapidly flowing fluids are contrasted.

2. The formation, in the interior of a streaming perfect fluid, of the wedge required by the displacement theory is shown to be impossible according to accepted hydrodynamical theory.

3. The formation, at the edge of a gas forming splitter in a cross blast, of the wedge required by the displacement theory is shown to be impossible according to accepted hydrodynamical theory.

4. High speed motion pictures of arcs extinguished in gas blasts are shown to contradict the displacement theory and support the diffusion theory.

5. Rough calculations are given which show that the turbulence which may be expected to exist in the extinguishing arc in gas blast breaker, may multiply diffusive effects by 100 or more.

6. This multiplication of diffusive effects is stated to be sufficient to make the diffusion theory adequate for accounting for the high interrupting capacity of gas blast circuit breakers.

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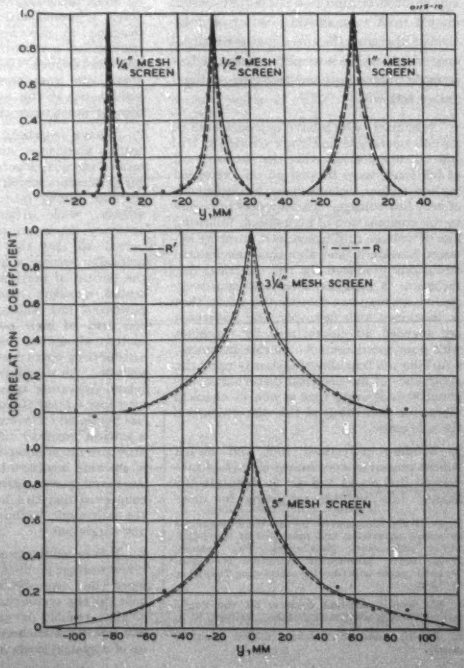

Figure 10. Curves showing variation of correlation coefficient with the cross-stream separation of the hot wires behind screens in wind tunnel, by Dryden

System Stability

F. W. GAY
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Synopsis: That the specter of a major system shutdown is prominent in the thoughts of many operators is evidenced by the 1939 symposium, covering methods of modernization of station-switching facilities, and the 1940 symposium, discussing means of restoring service to systems after a major shutdown. In this paper, system and apparatus performances are studied, during the period between the time allotted for the functioning of the high-speed relay protection, and the point where the system becomes so unstable that a major shutdown occurs. With a view to the further improvement of system operation, the paper studies:

1. Phenomena preceding and during instability;

2. Method of lengthening the period between the fault and instability;

3. A local high-speed back-up relay scheme;

4. Means of automatically and quickly stabilizing an unstable system; and

5. In case all of the above fail, progressive isolation of the system by zones selected by degree of low voltage.

THE length of time to reach the critical period of instability for severe types of faults, that is, a three-phase short circuit near a generating center, is relatively short and the three major phenomena which come into play within a few seconds, following persistent low voltage, are as follows:

1. Machines, which have demonstrated in normal operation that their overspeed trip will not operate following the throwing off of full load, have tripped off on overspeed in three to four seconds upon the occurrence of very low voltage. This appears to be due to the combination of high speed, following loss of voltage and hence load, hunting between machines, and abnormal mechanical vibrations produced by the electrical disturbance. A variation in the setting of overspeed trips may be a contributing cause, that is, machines with fast operating governors are speeded up (motorized) by machines with poor speed control. In rare instances, a turbine will trip almost instantly upon the occurrence of an electrical disturbance, apparently indicating that severe mechanical vibration, as a result of this disturbance, is the sole cause.

2. Modern pulverized fuel and oil-fed boilers require a continuous supply of pulverized fuel or oil and air to maintain the flame. Low voltage, persisting for more than a few seconds is very liable to upset the carefully balanced supply of fuel and air and to result in flame extinguishment. The boiler must then be restarted by hand to avoid a possible explosion. Temporary loss of steaming capacity results. Low voltage, persisting a still longer time, may cause circulating pumps and other vital auxiliaries to fail.

3. Generating stations, or even individual machines, may pull out of step and overspeed, resulting in heavy crosscurrents between generators and a further drop in the already low voltage.

Relief from the above conditions may be had as follows:

1. It is believed that a major portion of all generators on a system will be found to have overspeed trips which may have their trip latches forced back into position when running at speeds well over normal. On two modern machines, turning at 3,600 rpm and having overspeed latches, it was found possible to force back the overspeed latch which tripped at 110 per cent upon a reduction to 105.5 per cent and 103 per cent speed respectively. It should be possible, on most machines, to force back the overspeed trip and automatically return the machine to governor operation within a fraction of a minute after the overspeed latch has tripped. On many 3,600-rpm machines, the manufacturer requires that the turbine not be run at speed without steam flow for much more than 60 seconds.

2. Where switching facilities permit, essential auxiliaries may have their transformer circuits closely connected to one of the generators which may be tripped from the bus during periods of persistent low voltage, while other parallel sources of auxiliary power are simultaneously disconnected so that this generator will automatically become a house generator during the period of persistent low voltage. Essential auxiliary electric motors, serving powdered fuel boilers, should be of ample size and of high pull-out torque. Such motors should be capable of maintaining satisfactory operation down to 60 per cent voltage. An alternate method is to provide relays operating to clear the station bus after low voltage (below 60 per cent normal) has persisted for several seconds. Clearing a station bus may involve resynchronizing after the disturbance has passed and in such a case may involve a temporary loss of load. Auxiliary power transformers must be so connected that this load is not dropped by the automatic withdrawal from service of any single bus.

3. It is becoming generally recognized that, if low voltage persists on a system for much more than two seconds, it is necessary to split up the system into a number of parts so that trouble on one part of the system will not involve the others. This splitting up of a system leads to certain consequences which must be cared for by the operation of the system continuously in preparation for such a split-up; otherwise, some of the parts will have an excess of generating capacity while other parts will be deficient in generating capacity. That particular section of the system, on which the disturbance originated, may be short of generator capacity following the disturbance. It may, therefore, be necessary to drop load temporarily, either manually or automatically. Such reduction in load can probably best be accomplished by automatically reversing the normal function of feeder-voltage regulators and load-ratio control transformers so that, with a reduction of frequency below approximately 58 cycles, there will be a reduction in service voltage to the limit of this regulating equipment's capacity to buck down voltage. This low voltage will be maintained until normal frequency is closely approached.

Whenever a careful study is made following a system disturbance, it is found that communication facilities, which are adequate for normal operation, are inadequate to permit quick restoration of service following the disturbance. It is believed that eventually it may be necessary to install an entirely different type of communication system if it is desired to handle emergencies efficiently. One such system is suggested as follows:

The head operator at the time of the disturbance shall act as a broadcaster giving orders only, and his broadcast shall be audible to all parties who may have an interest in the orders given. His lieutenants will receive information from the field and set up this information in the form of a load dispatcher's board so that the head operator can visually note the actual instant condition of the system. The head operator's orders will carry to every generating station and switching station operator simultaneously and will include, at least, the turbine room operator, the boiler room operator, and the pump room operator in the generating stations so that each of these men will instantly know when their equipment is, or is about to be called on for increased effort. Any company executive or engineer can be plugged into this circuit and can follow the course of the trouble and the restoration of normal conditions.

Twenty important generators in the Public Service Electric and Gas Company system are, or soon will be, equipped with field adjusters. These field adjusters are inoperative during normal conditions, allowing machine-field strengths to be maintained by hand operation at or above stable values, and allowing reactive volt-amperes as well as watts to be allocated by the load dispatcher. Upon the occurrence of low voltage from any cause, these field adjusters operate instantly to add approximately one-third of normal field current to the field of each generator. Upon the return of normal conditions, the fields are automatically returned to their predisturbance value. The amount

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1. For all numbered references, see list at end of paper.

of field current added to each generator is chosen so that no injury should result to any field, even if the high-field current is maintained for many minutes. An alarm warns the operator of high-field current and a volt-ampere (ohm) chart indicates meter readings which must not be exceeded.

Persistent low voltage may so reduce the pull-out torque of a generator that it is unable to transmit to the connected low-voltage system the entire output of its connected turbine which is being supplied with a full quota of steam. The unit will speed up until the governor reduces the steam supply to balance the reduced load and the generator will then continue to run out of step as an asynchronous generator. If the unit is equipped with a field adjuster, it should not trip on overspeed.

The Public Service Electric and Gas Company are equipping five turbine-generators with resynchronizing governors which it is hoped, will overcome this difficulty. Associated with each of these governors is an out-of-step relay. This relay determines an out-of-step condition by reason of the simultaneous occurrence of heavy current and pulsating kilowatts. Upon the occurrence of such phenomena, the relays proceed to close the steam valve and this closing operation continues until the out-of-step relay determines that the generator has resynchronized. (This relay does not alter the setting of the governor, but closes the steam valve against the governor.) When the relay determines that the generator has resynchronized, it returns the unit to the governor by backing off slowly so that the rate of steam supply is changed relatively slowly.

The amount of time used to reload the turbine is proportional to the amount of time taken to resynchronize, that is, the rate of change of load is constant.

Instability is a function of voltage loss. It follows quickly on the heels of a severe voltage drop and more slowly for lesser voltage drops. The following is Mr. Dean's conclusion as stated at last winter's convention, and is a good summation of experience in this respect:

"It is interesting to note that the index upon which the necessity for emergency switching turns is the voltmeter reading. It has been found from experience that under fault condition, the behavior of current indicating devices is often so erratic as to make them undependable *and that persisting low voltage is about the only reliable criterion.*"

Figures 1 and 2 illustrate a suggested method of back-up relaying for a utility system, based entirely on low voltage. In figure 1, curve *T* shows the characteristics of a simple timing relay which operates to close its trip contacts for a voltage on any phase to ground below approximately 60 per cent of normal and its associated timer closes the trip contacts after an elapsed time of 32 cycles.

Curves *A* and *B* show the characteristics of timing relays which comprise a voltage element on each phase, operating to close the contacts of a timing element on that phase, for phase-to-ground voltage on any phase below a desired minimum. The timing element comprises a watt-hour meter and a rectifier operating across a resistance to normally charge a battery through this watt-hour meter.

A battery, allocated to each phase, is continuously charged from phase-to-ground voltage on that phase through a step-down transformer and full-wave rectifier. A watt-hour meter in this battery charging circuit is connected to operate in reverse for normal charging. A high-speed register on this watt-hour meter turns in reverse against a stop. For phase-to-ground voltages below a desired critical value, the battery discharges through the resistor and at a rate proportional to the drop in voltage below the desired critical value. During the battery-discharge period, the watt-hour meter turns its high-speed register to close the tripping contacts. The rate of closure is proportional to the drop in voltage below the desired critical value.

The multitrip relay opens the main battery-discharge circuit through the potentiometer resistance of the timing relay and the timing relay slowly resets. This circuit is also held open by the voltage element that operates the timing element described above. The reclosing of this circuit follows the reclosing of the multitrip relay only after the re-energizing of the cleared circuit.

For a meter adjusted according to curve *A*, the transformer and resistance taps are chosen so that the battery is discharging for phase-to-ground voltages below 40 per cent of normal and, when adjusted according to curve *B*, the battery is discharging for voltages below 80 per cent of normal.

A suggested use of these relays is illustrated in figure 2 wherein a system, *Y*, is connected to the *NY* bus of station *N*, having short-circuit capacity on the bus *NY* of 1,000,000 kva with system *Y* alone connected; that is, a per-unit reactance for system *Y* of ten per cent, based on 100,000-kva unit. The bus *NY* is shown connected to the red and blue busses of station *N* by transformers *T*-5 and *T*-6. These transformers are of the double-wound secondary type and have an equivalent primary negative reactance of minus 15 per cent (per unit of 100,000 kva) and an individual secondary reactance of plus 60 per cent. One of the secondaries of each transformer is shown connected to the red *N* bus and the other connected to the blue *N* bus. Additional stations *O*, *P*, and *Q* are shown with *N* and each have a red and blue bus. Load on each red bus is carried by transformers such as *NRT*, *ORT*, etc., each feeding a low-voltage load bus, *L*-1, and load on each blue bus is carried by trans-

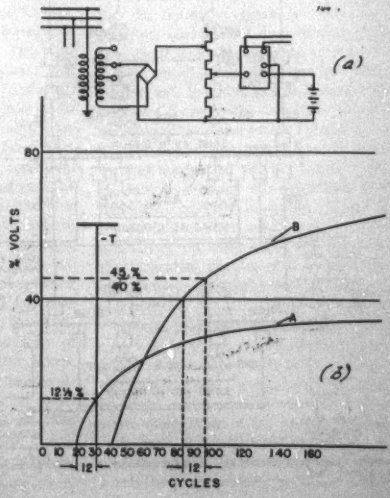

Figure 1a. Diagram of timing element in suggested relay scheme
b. voltage-time curves

Curve *A*—Timing element set for 20 cycles (maximum closing speed); range adjusted for operation between zero and 40 per cent volts

Curve *B*—Timing element set for 40 cycles (maximum closing speed); range adjusted for operation between zero and 80 per cent volts

formers such as *NBT*, *OBT*, etc., each feeding a low-voltage load bus, *L*-2. The *L*-1 bus is shown connected to the red bus of each station through a transformer having a per-unit reactance of 20 per cent and to a tie bus in common with *L*-2 through 20 per cent reactors. The *L*-2 low-voltage bus is similarly connected to the blue bus and the tie bus. At stations *P* and *Q* two 100,000-kw generators (125,000 kva) are shown, each connected to the red and blue bus through a two-winding secondary transformer having equivalent negative primary reactance of 15 per cent, and a secondary winding reactance of 60 per cent for each winding alone. One secondary of each transformer is shown connected to the red bus and the other secondary to the blue bus. The arrangement shown is identical at station *P* and at station *Q*.

If, now, it is assumed that a three-phase short circuit occurs on the terminals of the power transformer connecting the high-voltage blue bus to the *L*-2 low-voltage bus at station *P* (short-circuit *X*, figure 2) and further, that the relays on this short-circuited transformer bank fail to operate, then a three-phase short circuit will remain at *X* on the blue bus *P* until the *PBT* transformer breaker is opened. (This fault will also remain on low-voltage load bus *L*-2.) The short circuit will, in effect, be a bus short circuit. To this bus, as well as to all other busses, is shown connected a relay of the *A* type, figure 1. With zero voltage on the blue bus at station *P*, the type *A* relay battery will discharge its maximum current through the current coils of the wattmeter-relay element and the high-speed register will turn at maximum speed to close the tripping contacts. As shown on curve *A*, figure 1, these contacts will be closed at approximately 20 cycles after the short circuit occurs, and since the high-voltage breaker on the transformer feeding the *L*-2 low-voltage bus has not operated, all high-voltage breakers connected to the *P* bus will be tripped and the *P* blue bus will be killed within the next 12 cycles. If pilot wire or carrier current is available, the breakers at both ends of lines leaving the blue bus at station *P* may and should be tripped. Voltage-timing relays *T* are shown for the reactor tie busses connecting load busses *L*-1 and *L*-2 at each station. With a short circuit at *X*, figure 2, as shown, the voltage on the tie-reactor busses at stations *N*, *O*, *P*, and *Q* may be less than 60 per cent normal and, if so, these relays start functioning to trip the *L*-1 reactor breakers so that the red and blue busses at stations *N*, *O*, *P*, and *Q* may not be connected through the low-voltage reactor busses. With a short circuit at *X*, as shown, the blue bus at *P* will be removed from circuit before relays *T* operate and only the *T* relay at station *P* will function, due to the fault on its connected transformer bank.

A study of curve *A* will show that, for the arrangement shown, if blue busses at stations *O* and *Q* have a voltage in excess of 12.5 per cent of normal, there will be no danger of the type *A* relays on these busses beating the type *A* relays on the *P* bus. (See dotted lines in figure 1.) With the arrangement as shown, the voltage on the red bus during the short at

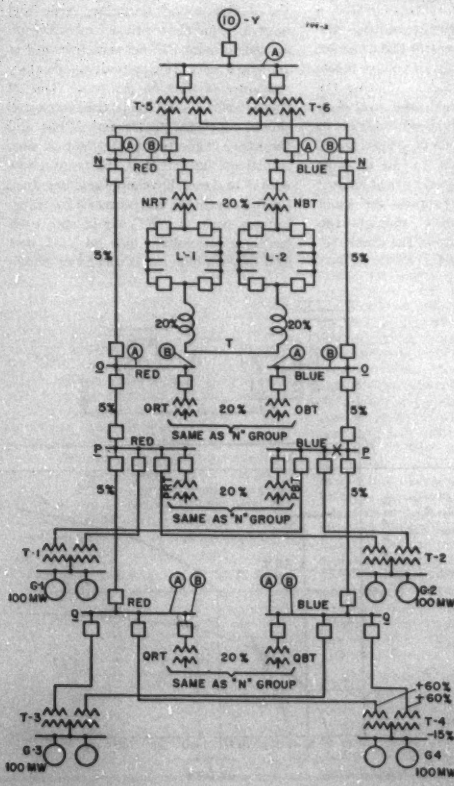

Figure 2. System layout

Employing three-winding transformers, each having a per-unit through impedance of 15 per cent (100,000-kva unit) and minus 15 per cent equivalent negative primary impedance, i.e., 45 per cent impedance through one high-voltage winding

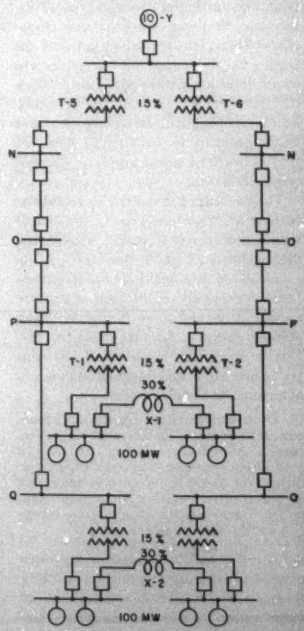

Figure 3. System layout

Similar to figure 2 but employing two-winding transformers each having a per-unit through impedance of 15 per cent (100,000-kva unit)

X will be over 100 per cent and on the blue bus at stations O and Q there will be a safe margin of voltage over the 12.5 per cent minimum required. The only load that will be lost will be that of the L-2 bus, connected to the faulted transformer bank. This bus may be reenergized immediately through the reactor circuits. A short circuit on any high-voltage bus should be cleared by this back-up relay scheme without danger of killing any adjacent bus. Curves A and B show that, as voltages, during a fault, become higher, the selectivity improves.

The use of relays with a B setting are required for protection against persistent low voltage originating outside the high-voltage circuit of the system under consideration as, for instance, trouble on the interconnected system Y. If the trouble is sufficiently serious to endanger service on the red and blue bus, the B relays at station N will function and are connected to trip the oil-circuit breakers of transformers T-5 and T-6. Again, if the generators or turbines at, for instance, station Q, should be in serious trouble, the B relays at station Q will function to open the output breakers of these generators.

No brief is held for the operating time used in this discussion except that the operating times closely approach the minimum. Longer times will obviously give greater selectivity.

The advantages of a relay scheme similar to the above are as follows:

1. Any generating station bus which has a voltage on it sufficiently low to cause hazard to auxiliary power-station equipment will be removed from service by the back-up relays in a period so short that the functioning of the auxiliary power equipment will not be seriously disturbed.

Note: With this system, auxiliary power transformers must be connected to generator circuits before these circuits reach the station busses, since station busses may be automatically killed in case of a bus fault.

2. A bus at any generating station will be removed from service so quickly that there will be no danger of unloading generators with consequent tripping of overspeed relays and temporary loss of capacity on the system.

3. The low voltage will exist for so short a time that system stability will not be in danger.

Figure 3 differs from figure 2, described above, in showing a more usual transformer arrangement at generating stations P and Q and interconnecting station N. All load circuits L-1 and L-2 are omitted in figure 3 in the interest of simplicity, as are the red and blue designations. A 100,000-kw (0.8 power factor) generator is shown connected directly to the primary of each of two 125,000-kva transformer banks, T-1, T-2, T-3, and T-4 and the transformer primaries at each station, as at P and Q, are shown connected together through reactors having a per-unit value of 30 per cent (100,000-kva unit). The six transformers, T-1, T-2, T-3, T-4, T-5, and T-6 in figure 2 and in figure 3, are shown to have a straight through reactance to balanced loads of 15 per cent; however, the two-winding transformers shown in figure 2 have an equivalent negative primary reactance of minus 15 per cent and a positive reactance of 60 per cent for each of the high-voltage windings singly so that the reactance from any individual generator to either the red or the blue bus will be 45 per cent for the transformer and, adding the generator subtransient reactance of 10 per cent, 55 per cent total to an individual bus. For balanced loading, the reactance from an individual generator to both busses will be 15 per cent for the transformer plus 10 per cent for the generator, or a total of 25 per cent, and will be the same for both figures 2 and 3. If, in figures 2 and 3, a badly unbalanced condition is considered, that is, 60 per cent load on each of the blue busses against 40 per cent load on each of the red busses as shown, and the generators are loaded to capacity and there is no interconnection load, we find that the total load on the blue bus will be 240 mw and 180 mvar (300 mva) and on the red bus 160 mw and 120 mvar (200 mva). Each transformer shown in figure 2 will be equally loaded, that is, it will have 125 mva on its primary winding and 75 mva on one secondary winding and 50 mva on the other secondary winding. The total loss in each transformer in figure 2 will be approximately 102 per cent of normal, indicating that a small amount of additional copper will have to be added for both high-voltage windings above that required for a balanced load condition. In contrast, in figure 3 it is seen that the two transformers connected to the blue bus must take the maximum load, in both their primary and secondary windings, that is, the transformers will carry 120 per cent of the normal generator rating and will have 144 per cent load loss. The transformers in figure 3 must, therefore, have a continuous-carrying capacity of 150,000 kva per bank. In other words, the single-winding secondary transformers, shown in figure 3, must be something more than 15 per cent larger than the double-winding secondary transformers shown in figure 2. Furthermore, with the instantaneous reactances given, should there be a fault at X, as shown on the blue bus for station P, the voltage of the generator connected to transformer T-2 will be approximately 82 per cent at the instant of fault, while the corresponding voltage at generator terminals in figure 3 will be approximately 63 per cent.

Assuming that all generators are of the modern type, equipped with field adjusters and having a sufficiently high-exciter ceiling voltage to maintain approximately 200,000 kva per generator through the fault, the sustained voltage, with the arrangement shown in figure 2, will be approximately 90 per cent for each of the generators connected to the red and blue bus in station P, and 48 per cent for the generator connected to the blue bus in the arrangement shown in figure 3. Furthermore, since the blue bus at station P is short-circuited, synchronizing power for generator G-2 is through reactor X-1 to generator G-1 only. It is obvious that generator G-2, shown in figure 3, will fall out of step and run above synchronism in the assumed case of failure, that is, relays fail to clear the faulted transformer bank PBT, feeding load bus L-2 so that the blue bus at station P remains short-circuited.

In figure 2, both generators G-1 and G-2 are equally affected by the fault at X and also both generators are connected to the red bus and will not pull out with respect to each other or be unloaded and run over speed. Furthermore, the voltage of the red bus will be over 100 per cent of normal and there will be a powerful synchronizing tie to generator G-3 and G-4 at station Q over the line connecting the red busses at these two stations. Phantom current will flow through the line connecting the blue bus at station P with the blue bus at station Q. This current will flow due to the mutual inductance between the two high-voltage windings of the transformers T-1 and T-2. This phantom current will flow directly through the faulted blue bus but not into the fault and will serve to maintain a low impedance between generators G-1 and G-2 on the one hand, and generators G-3 and G-4 on the other hand, and between the individual generators G-1 and G-2 and between the individual generators G-3 and G-4.

Several years ago, a small model system was set up to determine if the impedance between two machines connected by two parallel transmission circuits could be maintained substantially constant while either of the connecting circuits were simultaneously grounded on all three phases. It was found that, with a relatively enormous equivalent nega-

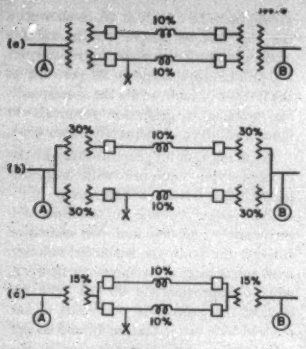

Figure 4

(a)—Simple two-circuit transmission system employing terminal transformers, each having two separately insulated high-voltage windings. Each transmission circuit served by an individual high-voltage winding at each end

(b)—Same as (a) above but each transmission circuit having its own transformer at each end

(c)—Same as (a) above but a single transformer at either end serving both transmission circuits at that end

tive primary impedance in the transformers at both ends of the lines, either connecting line could be short-circuited and the voltage on the nonshort-circuited line would be instantly doubled. The power would flow over the nonfaulted line at double voltage and a phantom power current of substantially equal value flowed over the short-circuited line but did not enter the short circuit.

As the equivalent primary negative impedance of the transformers at both ends of a dual circuit transmission is reduced by design from a relatively enormous value to zero, the effect of a single-line short circuit on the through impedance will be found to change, having substantially no effect for very high negative and double the impedance for no negative.

The value of equivalent-negative primary impedance in reducing fault currents has been well covered in the technical press but the value of such negative impedance in maintaining a stable system seems to have been neglected.

In order to better assure the reliability of large capacity, closely coupled systems, it is believed that operators and manufacturers must find some solution to the factors causing instability outlined in this paper. While the experiences described cover those of one system only and the remedies suggested have had very limited or no field trial, it is hoped that after further development they will prove of substantial value.

Appendix

A two-circuit transmission system was set up on the circuit analyzer to determine the characteristics of a double-wound high-voltage transformer bank having various amounts of equivalent primary negative impedance.

Figure 4 (*a*) is a one-line diagram showing a hypothetical system *A* having infinite capacity connected to a like system *B* by a transmission circuit comprising two transmission lines, each having ten per cent reactance (100,000-kva unit) and being serviced by a transformer at each end, having a single low-voltage winding and two high-voltage windings. Each transmission line is served at each end by an individual high-voltage winding.

Figure 4 (*b*) shows a somewhat similar circuit connecting the two systems *A* and *B*. In this arrangement individual transformers are used in each transmission circuit, each transformer having twice the through impedance of the transformer shown in (*a*) above, that is 30 per cent.

Figure 4 (*c*) shows the same two systems, *A* and *B*, connected through individual transformers to the same two circuits. It is obvious that in normal operation, the performance of the three systems, *a*, *b*, and *c* will be identical, since the through reactances are the same and resistances are neglected.

If a three-phase fault is applied at *X* in each of these systems, it will not be possible to transmit any power between the system *A* and the system *B* with the arrangement shown at (*c*), while with the arrangement (*b*) the power transmitted between system *A* and system *B*, with the three-phase fault existing, will be only one-half the amount that may be transmitted without the fault. (The current flowing from systems *A* and *B* into the fault is of no consequence since these systems are assumed to have infinite capacity.)

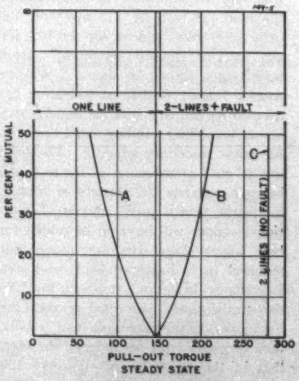

Figure 5. Steady-state pull-out torque of system shown in figure 4a

(*a*)—Variation of steady-state pull-out torque with per cent mutual for a single line in circuit, i.e., the faulted line cleared at both ends

(*b*)—Variation of steady-state pull-out torque with per cent mutual for two-line operation and a three-phase fault on one line at *X*

(*c*)—Variation of steady-state pull-out torque with per ce t mutual for two-line operation

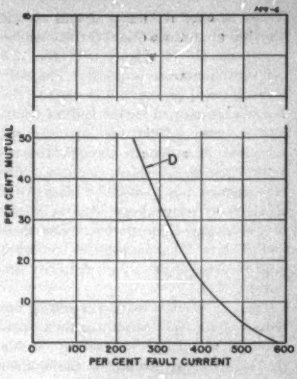

Figure 6. Variation of fault current with per cent mutual

In arrangement (*a*), if the equivalent negative primary impedance (per cent mutual) in the transformers is a maximum by design, then the current that will flow into fault *X* will be negligible, and the transmitting characteristics of the circuit shown in (*a*) will be the same whether the three-phase fault at *X* is present or clear. If the fault is on, the voltage on the nonfaulted line will be 200 per cent. The current flowing in the faulted line will be identical to that flowing in the unfaulted line. This current is called a phantom current and is induced in the faulted line by the mutual impedance in the transformer circuits. As the mutual impedance is diminished, the volts on the sound line during the fault will diminish and the phantom current in the faulted line diminishes.

Figure 5 shows the characteristics of circuit (*a*). The steady state pull-out torque in per-unit (100,000-kw unit) will be approximately 280 per cent, with both lines in circuit and without a fault. This pull-out torque will be a constant, regardless of the amount of equivalent primary negative impedance (per cent mutual) built into the terminal transformers, so long as there is no fault on either transmission circuit. If however, there is a fault on one circuit, the steady-state pull-out torque is shown by curve *B*. This pull-out torque will reduce with a reduction in equivalent negative primary impedance and for zero negative the circuit is the equivalent of (*b*), and the steady state pull-out torque will, of course, be one-half of what it is with an unfaulted line. If now the faulted circuit is opened at both ends to clear the fault, the transmission will be left with a single circuit and

The Water-Cooled Steel-Tank Rectifier Corrosion Problem

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Synopsis: The first mercury-arc rectifiers utilized glass tubes and consequently the physical size and electrical capacity was limited. The efforts to increase the available output led to the development of water-cooled steel-tank vacuum chambers after many years of research and the solution of many problems. This paper is primarily concerned with the solution of the problem presented by corrosion. Corrosion is essentially the returning of a metal to its original state and the problem consists in finding a means to retard the return sufficiently so that corrosion will not be a limiting factor in the life of rectifiers.

Analysis of the problem indicates that pitting corrosion causes the greater damage and is largely a function of the character and condition of the metal, the quantity of electricity passing, and also that it is self-propagative. The rate of corrosion is affected by the temperature of the cooling water, the chemical constituency of the water, and potential differences between points on the surface of the rectifier tank.

The first efforts in the solution of the corrosion problems were directed toward finding a protective coating to isolate the steel tank from the cooling water. Various paints, varnishes and lacquers, and enamels were investigated, as well as sprayed metal, but were not found satisfactory. Chemical treatment of the water was then investigated and sodium chromate found to give excellent results. The action of this chemical is reviewed and both laboratory and field evidence of its effectiveness submitted, followed by a discussion of the various factors to be considered in the application of this chemical to prevent corrosion.

Introduction

WITH few exceptions, all machines for the generation and conversion of electrical energy have been mechanical in nature. During the early part of the present century, Cooper-Hewitt and Steinmetz presented to the electrical world a conversion unit for transforming alternating current to direct current which was nonmechanical, but electronic in nature. This conversion unit known to us as the glass-bulb mercury-arc rectifier, has since its introduction won wide acclaim as an efficient, practical converter. Because of the fragility of glass, the physical size and current rating of the mercury-in-glass rectifier has been essentially limited. The desirable features of this particular type of converter are as follows:

(*a*). High operating efficiency
(*b*). Silent operation
(*c*). Absence of moving parts
(*d*). Comparatively long life

Studies were soon begun to increase the current rating, operating potential, and naturally its physical size. As it was impractical to increase the physical size of the mercury-in-glass rectifiers, a substitute for glass was sought. This investigation which was carried on by several groups, both in the United States and abroad, resulted in the adoption of the steel-tank vacuum chamber. Subsequent investigations indicated that by surrounding the steel vacuum chamber with a water jacket, the heat losses[1] could be effectively removed and the rating of the rectifier considerably increased. This transition from the glass to steel vacuum chamber and the increase in rectifier rating required several years of research and necessitated the solution of many problems before this new rectifier was available for service in the field. It is the purpose of this paper to explain the steps taken to overcome one of these problems, namely the corrosion problem, which became evident during the early days of the water-cooled steel-tank rectifier field performance. While this subject does not pertain to the phenomena of rectification, nevertheless, its immediate solution was necessary in order to give the assurance that the life of the water-cooled steel tank rectifier would not be limited by corrosion. This assurance would make its future manufacture and application economically justifiable.

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1. For all numbered references, see list at end of paper.

The Corrosion Problem

Water when available in sufficient quantities is one of the most practical and economical mediums for controlling the temperature of machines. Likewise, iron is one of the most practical and economical metals for the fabrication of machines.

The application of water in contact with iron presents to the manufacturer and operator of electrical apparatus, the so-called "corrosion problem." This problem presents itself in varying degrees, occasionally of no consequence, and then again if not retarded, considerable damage results. This damage may appear as loss of good will, interrupted service, or expensive repairs. The performance or the life of electrical or mechanical apparatus of the present day should not be determined by the corroding away of the water-cooled iron parts.

Because of the many different theories regarding its nature, corrosion is generally studied from an academic point of view. When one studies the many possible causes for the corrosion of iron, one can readily appreciate why the early students of the corrosion problem, asked themselves, why ferrous metals survive corrosion at all.

Corrosion of metals is essentially the reverse of smelting, or in other words, corrosion is the returning of a metal to its original ore state. As corrosion in the theoretical sense cannot be entirely stopped, nevertheless, we must find means to retard it sufficiently so that corrosion will in no way be a factor to impair the performance or limit the expected life of apparatus, especially where water is used as a coolant.

The temperature of steel-tank rectifiers of early manufacture were controlled by tap water cooling, using whatever water was available for the purpose. In locations where water from city mains was not available, wells were provided near the station. As the quantity of water available was the criterion rather than the quality, many of the waters corrosive in nature were used as a coolant. The more corrosive waters attacked the iron parts of the rectifier and subsequently advanced stages of corrosion

with this single circuit, the one-line steady state pull-out torque will vary inversely as the negative impedance (per cent mutual), diminishing with an increase in such impedance in accordance with curve *A*. The current in the fault *X* will vary with equivalent primary negative impedance having approximately 580 per cent value for zero negative impedance (per cent mutual), and diminishing along the curve *D* to have a zero value for an infinite negative impedance (figure 6).

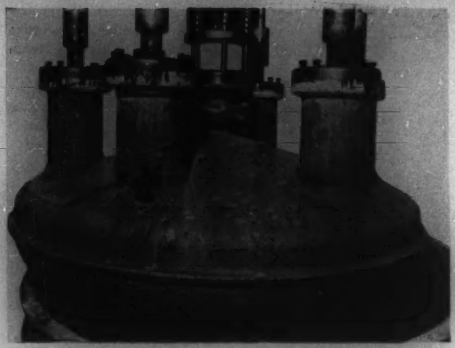

Figure 1. Tubercles on mercury-arc-rectifier vacuum chamber

were noted, some instances resulting in vacuum leaks in the rectifier or water leaks in the water jacket.

The Corrosion Study

Examination of the corroded parts of various rectifiers indicated that pitting corrosion rather than the so-called general corrosion was causing the greater damage. In "general corrosion" the anodic and cathodic areas which characterize all corrosion attack by water on iron are evenly distributed and of such fine grain, so to speak, that the net attack is fairly uniform and so slow as to be unimportant. This effect is largely a function of the character and condition of the metal. No way is known to insure that corrosion attack shall be confined to this type. "Pitting corrosion" occurs when positive anodic areas are set up surrounded by relatively large cathodic areas. This may result from patches of mill scale or other foreign matter or from inhomogeneity of the metal, as at welded junctions. It is the usual situation in fabricated structures since anodic areas are essentially areas of oxygen starvation. The resultant pitting is self-promoting: The condition once established tends to become worse. Figure 1 shows the presence of tubercles of iron oxide resulting primarily from pitting corrosion. These tubercles are small mounds which grow in size in proportion to the quantity of electricity passing between the covered portion acting as anode and the surrounding metallic surface acting as cathode, and are generally found at welded junctions, breaks in mill scale or at a point where a foreign substance is attached to the iron. From within the tubercle or pit anodically produced iron salts diffusing outward meet a relatively alkaline water from the cathodic area whereby the iron is precipitated forming mounds of black magnetic iron oxide, which further obstruct the access of oxygen. Being loose and not adherent, they do not constitute a protective film. Deposits of this nature, when not removed and the pits repaired or thoroughly cleaned, ultimately cause perforation of the water jacket. Tubercles shown in figure 1, occurred at the hottest point and on a welded surface. Figure 2 shows the surface of a rectifier water jacket before cleaning. Many tubercles and much water sediment is evident, with a fertile field for corrosion. Figure 3 shows the cleaned surface, with the pits in the iron jacket plainly visible. It is readily seen that such disintegration if allowed to continue will reduce the active life of apparatus. The application of sodium chromate even in this advanced stage will stop corrosion and make corrosion no longer the limiting factor of the machine's life. This preliminary study taking into consideration the several variables all conducive to corrosion, placed the rectifier corrosion problem in a category of its own. These variables may be enumerated as follows:

The rectifier water temperatures are variable, often ranging from tap water temperature to boiling water temperature.

The waters in different localities also differ in chemical composition.

During operation the steel tank rectifier has inherent differences in potential between points on its surface.

The rate at which corrosion occurs, is greatly increased with increase in temperature. This is due mainly to the fact that both the electrical conductivity of an electrolyte and the rate of chemical action increase with temperature. It is for this reason that water-cooled parts of rectifiers operating in excess of 50 degrees centigrade corrode at a considerably higher rate than those operating at lower temperatures.

It is of interest to note the differences in chemical constituents of the various waters used as rectifier coolants throughout the United States. These waters are classed as lake waters, river waters, mountain spring waters, and local well waters. The following table shows the extremes, in parts per million (ppm) of the constituents in these various waters:

	Maximum	Minimum
Total hardness ($CaCO_3$)	370	3
Total dissolved solids	353	19
Silicon (Si)	39	1.6
Iron (Fe)	1.4	0
Calcium (Ca)	107	0.8
Magnesium (Mg)	25	0.2
Sodium (Na) Potassium (K)	74	1.2
Bicarbonate (HCO_3)	289	7.3
Sulphate (SO_4)	120	1.7
Chloride (Cl)	44	0.7
Nitrate (NO_3)	25	0

The excess of some of the constituents listed in the above table are harmless, while the excess and combination of others provide fertile grounds for corrosion.

The presence of calcium carbonate is nearly universal. Where it is not associated with an excess of free carbonic acid it tends to precipitate along with the rust on iron surfaces forming a dense scale which resists further corrosive attack. In fortunate cases, the accumulation of this scale is so slow that it does not cause troublesome interference with heat transfer. Where, on the other hand, an excess of free carbonic acid is present deposition of calcium carbonate is prevented and the water becomes "aggressive" toward iron.

The first step in the search for a remedy of the rectifier cooling system-corrosion problem was naturally to find a protective coating which would perfectly isolate the iron parts of the rectifier from the water of the cooling system and thus prevent corrosion.[2] Asphaltum, metallic and metallic oxide paints recommended for their corrosive-preventive merits were studied. Varnishes and various lacquers were investigated. The corrosion-resisting properties of sprayed molten metals and their combinations were likewise investigated. Both air drying and baked vitreous enamels applied to iron surfaces were given vigorous tests.

The tests revealed that the binder in many of the air-drying applications would dissolve in warm water, while others would dry sufficiently porous to permit corrosion to develop.

It was also found that sprayed metal

Figure 2. Tubercles on mercury-arc-rectifier water jacket

Figure 3. Electrolytic corrosion on mercury-arc-rectifier water jacket

would not make a sufficiently homogeneous surface to prevent water from reaching the iron. Similarly it was discovered that metals near the alkali end of the electromotive-force series would not long withstand the solvent action of the water. Therefore the effective life of metals of this nature would depend on the thickness of the coating.

Enameled surfaces in iron were found not sufficiently homogeneous to retard electrolytic corrosion. The application of vitreous enamels in preventing corrosion of rectifier surfaces was found very detrimental because any microscopic hole or crack in the enamel surface would take the total electrolytic current for the section and thus in a comparatively short time sufficient disintegration would occur to cause a vacuum leak.

Following the negative results of this initial investigation, it was decided to study methods of chemically treating the circulating water. For this test commercial corrosion-preventive liquids, oils, and many miscellaneous chemicals were studied. These were studied at constant and varying temperatures for their general and electrolytic corrosion-retarding qualities.

The study revealed several more or less promising treatments of the water for retarding general corrosion under the operating conditions of power rectifiers, but only one, a soluble chromate, $Na_2CrO_4 10H_2O$, effectively controlled both general corrosion and the intensified action due to electrolysis.

Sodium dichromate $Na_2Cr_2O_7 2H_2O$, is usually used to supply the chromate for a corrosion-inhibiting solution, because this salt is readily obtainable and is of low cost. Many natural waters are sufficiently alkaline to convert this to the chromate. Where this is not the case it is advisable to add the requisite alkali. This does not materially affect the anticorrosive action of the chromate, but may prevent a rapid loss of the chromate from certain unwanted side reactions due to impurities in the water.

As an example of the effectiveness of a sodium chromate-treated coolant, the photograph figure 4 is submitted, showing three iron electrodes, all immersed in their respective containers for 12 days. The electrodes were immersed in separate containers, *A*—the positive electrode of a cell containing Schenectady tap water, *B*—the positive electrode of a cell containing a one-half per cent solution of sodium chromate using Schenectady tap water. A five-volt potential was impressed between the electrodes of the two cells. Electrode *C* was placed in a container of Schenectady tap water, with no potential impressed. Electrode *C* is an example of the so-called general corrosion, a fairly uniform covering of reddish-brown iron oxide. No tubercles or concentrated corrosion is noted on this specimen. Electrode *A* shows the effect of electrolytic disintegration, much of the iron having been removed by the effect of the few milliamperes of current. As a contrast, electrode *B*, which was immersed in a sodium chromate solution shows on microscopic examination no evidence of either the so-called general or concentrated form of electrolytic corrosion. It is interesting to note that by virtue of the relatively high electrical conductivity of the sodium chromate solution, approximately ten times as much current was passed between the electrodes of this cell in comparison with electrodes of the cell containing tap water and electrode *A*. Subsequent tests where the cell current was increased several hundred per cent, indicated that even with this unusual current, the one-half per cent solution of sodium chromate was capable of inhibiting electrolytic corrosion.

This passivating action of the chromate is somewhat complex. Recent research[3] indicates that it is not a simple oxidizing action. Other powerful oxidants such as the permanganates and

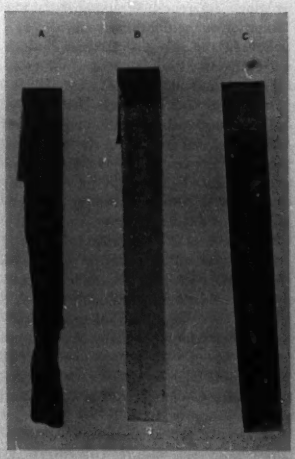

Figure 4. Three iron samples after corrosion test

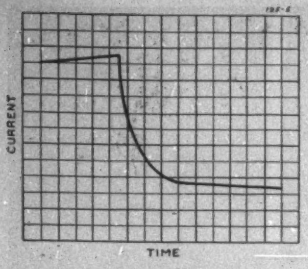

Figure 5. Current characteristic during growth of protective chromium film

hydrogen peroxide produce no such effect. The effectiveness of the protective oxide film produced, appears to be due not only to the simple production of a film of iron oxide but also to the inclusion of chromic oxide in the precipitate or rust formed in the simple corrosion reaction. This so modifies it that a dense and adherent protective film results rather than a loose nonprotective rust or tubercle. Of these factors the inclusion of Cr_2O_3, is probably the most important as the other action is also common to other oxidizing agents which have less or no protective effect.

The growth of the protecting chromate film is an interesting phenomenon, as shown in figure 5. With the deposition current as abscissa and time as ordinate we see what normally occurs in a few seconds or a few minutes, depending upon the chromate concentration and the existing difference in potential. The formation of the film takes place quickly, and then the deposition current which generally is of the nature of a few milliamperes, gradually recedes as the thickness of the film increases. Ultimately, the current reaches a minimum value. Laboratory cell tests made to determine the proper concentration of sodium chromate indicated, as would be expected, electrolytic corrosion at the positive terminal when untreated water is used. By the addition of a small amount of chromate it was noted that the effects of electrolytic corrosion became more pronounced. With each subsequent small increase up to a certain amount, the effects of electrolytic corrosion increased proportionally. When the critical amount was exceeded, it was noted that the evidence of electrolytic corrosion abruptly stopped.

The resistance of chemical solutions varies with their nature, concentration, and temperature, the higher-temperature solutions being the better electrical conductors. The chromate solution of the concentration used as the rectifier coolant is many times the better electrical conductor than is the average tap water. This fact is shown in the curves figure 6, where the electrical conductivity of Schenectady tap water and sodium chromate solution are shown at increasing temperatures. These relative curves show the trend of their respective conductivities as measured with one-sixteenth-inch diameter wire electrodes at a distance of one inch, and with current values approximating those found passing between different parts of the rectifier cooling system. The important consideration of these curves is that ample lengths of insulating coolant conductors must be provided between points of different electrical potential; so that the amount of leakage current will be negligible.

The application of chromate as a corrosion inhibitor is by no means new. Solutions containing chromate have been used for many years in the retarding of the general corrosion of iron.[4] The application of a sodium chromate coolant to specifically retard pitting corrosion in the steel-tank power rectifier, apparently is a new field of service.

The Applications of Sodium Chromate

The laboratory tests revealed that a one-half per cent solution of sodium dichromate was sufficient for the average water used as a rectifier coolant. This strength of solution has been found to be sufficient to inhibit corrosion when the solution is made up of any waters of potable purity. Where waters are available which are of exceptional purity, then it is possible to reduce the percentage of solution. A safe solution percentage can be determined definitely by the electrochemical means, explained below. Naturally the safest solution is made using distilled water, where the absence of foreign chemicals which would tend to react with the sodium dichromate and thus limit its life as a corrosion inhibitor is assured. Solutions made up of potable waters containing an excessive amount of chloride will require the full amount of sodium dichromate in order to obtain the full corrosion protection of the dichromate solution.

Before installing anticorrosive treatment in rectifier cooling systems, it is essential that all metal surfaces be perfectly clean. The coolant is made by adding a sufficient amount of the orange-colored sodium dichromate crystals of technical purity, to the water of the cooling system. A one-half per cent solution requires 4.2 pounds of the crystals to every 100 gallons of cooling water. The crystals are readily dissolved in cold or warm water and as soon as added to the system the coolant should be circulated.

The following method of checking the effectiveness of any given treated water has been found convenient and practical. A sample of the solution is placed in a glass bottle provided with two iron-wire electrodes spaced about one inch apart. Impress approximately five volts d-c potential across the electrodes. Should the solution be weak, a grayish-colored formation or precipitate will become visible within 5 to 30 minutes about the positive electrode, indicating anodic attack which may also be seen on close inspection of the electrode. The solution should then be strengthened and the test again repeated. Should the solution be of sufficient strength to retard corrosion, no precipitate will form around the electrodes. In order to eliminate any possible external influence, it is desirable that all such tests be made at a specific solution temperature maintaining the same size of bottle and dimensions for the electrodes.

Field Experience With Sodium Dichromate

Sodium dichromate has been used as a corrosion inhibitor in the steel-tank power rectifier since 1930. Since this time, all rectifiers in which the inhibitor solution was properly maintained have been free from both the general and concentrated pitting corrosion. Prior to the application of sodium dichromate, the temperature of practically all steel tank rectifiers, was controlled by tap water cooling. At the present time only 12 per cent of the rectifiers have tap-water temperature control, the remaining 88 per cent are provided with recirculating cooling sys-

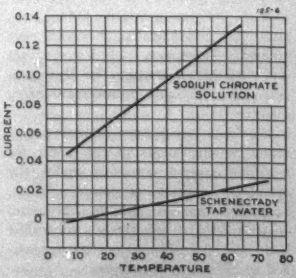

Figure 6. Electrical conductivity versus temperature

tems and treated water. Of the rectifiers originally operating with tap water cooling, approximately 25 per cent have experienced corrosion trouble terminating in vacuum leaks.

The life of a sodium dichromate solution depends upon the amount of make-up water added to the closed circulating system, and also on the chemical nature of the raw water. Our experience indicates that some solutions using mountain waters which are essentially pure, have a life in excess of three years. Well waters which are potable but have a higher impurity content, when made into an inhibiting solution have a life ranging upward from nine months. As already indicated, it has been found that the addition of small amounts of caustic soda (NaOH) to the chromate solution would increase its effective life. The function of the soda is to convert the inhibitor to a neutral chromate. A proportion of 1.5 (NaOH) to 5 ($Na_2Cr_2O_7 2H_2O$) ordinary crystalline dichromate, is sufficient in most cases. Slightly more (NaOH) than this proportion will do no harm. It has been found desirable to make periodic electrochemical examinations of the efficiency of an inhibiting solution; this can be done monthly or semiannually, depending upon the chemical nature of the water used, and the amount of water added for make-up.

Figure 7 shows the rectifier tank indicated in figure 1, but following the application of sodium dichromate. This rectifier had previously operated on a closed cooling system using untreated water, during which time the carbuncles, some shown in figure 1 had produced the pitting indicated. Following the first 11-month application, no new indications of pitting were evident and the vacuum chamber was in a clean condition as indicated in figure 7. Since this photograph was taken, this rectifier has been operating continually for the past six years without corrosion troubles.

Various Types of Cooling Systems

Sodium dichromate coolant is equally as well adapted to either water-to-water or water-to-air type of temperature regulators. The application of either type depends naturally on the particular installation. Locations such as the railway subways, where a comparatively high ambient temperature prevails at all times, the water-to-water temperature regulator is the most satisfactory. In such cases where the prevailing ambient temperature is slightly below the operating temperature of the rectifier, water-to-air temperature regulators can be applied.

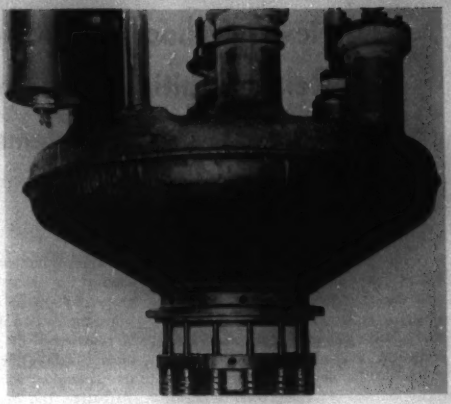

Figure 7. General Electric mercury-arc-rectifier vacuum chamber after eleven months' operation with sodium dichromate coolant in place of tap water showing corrosion arrested

Water has been found to be the most practical coolant where the heat to be removed is relatively high. In apparatus where the watts per square inch are relatively low, forced air, or circulating oil may be utilized. For certain applications, such as the cooling of rectifier mercury-condensation pumps, tap water cooling is the most practical. Here the amount of heat to be removed is small, the rate of water flow is low and the apparatus to be cooled is relatively small. The apparatus being small, makes it possible to confine the water cooling system in a copper jacket or copper cooling coils.

Low Ambient or Freezing Protection

Water cooling systems utilizing the recirculating principle can be protected from freezing by maintaining a higher temperature by means of jacket water heaters or by the use of a nonfreezing solution. Both systems have been found practical. Where tap water cooling is used, it may be necessary to lag the water piping sufficiently to prevent freezing, and insure that a constant water flow is maintained.

Maintenance of Cooling Systems

All cooling systems require a certain degree of maintenance, depending upon the nature or chemical content of the water used.

Closed cooling systems utilizing sodium dichromate as corrosion inhibitor have been found to require the least attention. Many systems have operated for several years without the necessity of cleaning.

Tap water-cooled apparatus must be descaled frequently to prevent water stoppage. Here again the frequency of cleaning will depend upon the amount of mineral water in solution and the amount of matter in suspension, both of which will eventually clog the water system. Copper water piping is no exception. It also readily scales, but naturally will not corrode as iron pipe does. Water containing excessive amounts of chlorine has increased corrosion effect on iron piping. Water containing much algii, or manganese dioxide, makes frequent cleaning of the water system necessary.

Electrical Insulation of Water Systems

In order to insulate a water-cooled apparatus or a part of the apparatus from parts of higher or lower potential, the coolant is conducted through insulating tubing such as rubber hose or rigid tubing. The two ends of an insulating tubing containing a coolant in general form the terminals of an electrolytic cell. It is natural that electrolytic disintegration will be expected at the positive terminal with electrolytic deposition on the negative end. In order to retard the accelerating form of corrosion in the cooling system, so-called "electrolytic leads" have been applied which consist of a long metallic rod of positive potential which gradually disintegrates whenever a difference of potential exists in between the ends of the insulating tubing. The disintegration of the metallic rod prevents the metal ends of the insulating tubing from disintegrating and will last several months or years, depending upon the prevailing

A New Method for Introducing Relaxed Initial Conditions in Transient Problems

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IN the calculation of transients in linear electrical and mechanical systems by the classical methods of differential equations, the constants of integration which arise in the solution are ordinarily evaluated from the initial values of the dependent variable and its derivatives.[1,2] The process of finding the initial derivatives is sometimes difficult for even rather simple systems, and the difficulties are particularly pronounced when the system of equations has undergone a change of variable to remove variable coefficients, as for example in Park's equations for the synchronous machine.[3] The purpose of this paper is to present a new method by which the initial derivatives can be found for an initially relaxed system (all currents in inductances and all charges on condensers initially zero) by a manipulation of the final differential equation itself. The solution for a nonrelaxed system can be found from the relaxed solution by superposition or by means of a systematic change in the original differential equations themselves, as is commonly done in operational calculus.[1,4,5]

The Differential and Integral Operators

The procedure in determining initial derivatives directly from the differential equation is based on the properties of the differential operator p (sometimes designated instead by the symbol D) and the integral operator $1/p$. It is shown in elementary treatments of linear constant-coefficient differential equations that if the derivative dy/dt be written py, where p indicates the operation d/dt, then p has many of the manipulative properties of an algebraic coefficient. Thus the second derivative d^2y/dt^2 can be represented by $p(py)$ or p^2y, and the integral with respect to time $\int y\,dt$, being the operation which cancels the first derivative, can be written symbolically $(1/p)y$. Similarly the iterated integral $\int\int \ldots \int y dt$ is written $(1/p^n)y$.

In an initially relaxed system, all currents and voltages are zero for negative time. It is therefore possible in such a system to interpret the indefinite integral operator $1/p$ to mean the definite integral from 0- to t. The assignment of these limits does not interfere with the previous definition of $1/p$ as the indefinite integral, for the variable upper limit t provides this indefinite integral, and the lower limit merely supplies the proper constant of integration.

Examine next the integral $\int_{0-}^{t} y\,dt = (1/p)y$ as the upper limit of integration t approaches zero. It is evident from elementary integral calculus that under this condition the value of the integral approaches zero also, provided that y is not infinite at $t=0$. Thus we can write the useful relation

$$\lim_{t \to 0} \frac{1}{p}\, y = 0 \qquad (1)$$

which holds whenever the system is without energy at $t=0$, provided that y is finite at this time.

It will be observed that it is the quantity $(1/p)y$ and not $(1/p)$ itself which is zero at zero time. This is because $1/p$ is an operator and not merely a multiplier. The distinction will save much confusion, since if we wrote $1/p=0$ we should feel obliged to write $p=\infty$ at $t=0$. This, of course, is not correct, and will be avoided by observing that $(p)y$ is not the reciprocal of $(1/p)y$, and hence is not necessarily infinite when $(1/p)y$ is equal to zero.

The Problem

In the usual circuit problem a differential equation is set up for each mesh of the network, using Kirchhoff's laws. By expressing all of the derivatives and integrals in operator form and by manipulating the operator p as an algebraic coefficient, algebraic methods of solving simultaneous equations can be used to eliminate all of the dependent variables (e.g., currents) except the desired one. In doing this care must be exercised not to take any indicated derivatives but instead to retain all p's in operator form. By convention all operators are written to the left of the currents and voltages on which they operate. The resulting differential equation in terms of the desired variable is of the general form:

$$\phi(p)i = F_1(p)e_1(t) + F_2(p)e_2(t) + \ldots \qquad (2)$$

in which

$e_1(t)$ is the voltage (in general a function of time) impressed in mesh number 1
$e_2(t)$ is the voltage impressed in mesh number 2, etc.
$\phi(p)$, $F_1(p)$, $F_2(p)$, etc., are polynomials in p

The polynomial $\phi(p)$ is generally as high or higher in degree of p than $F_1(p)$, $F_2(p)$, etc. If $\phi(p)$ is lower in degree of p than some $F(p)$, as is the case when solving for the current in a circuit in which a complete path through condensers exists between input terminals, the response i may contain an infinite impulse at $t=0$, and equation 1 will no longer hold. This difficulty can be eliminated by rewriting the differential equation in terms of charge q, where $pq=i$, and later taking the derivative of the solution for q to find the form of i.[1]

It is known from differential-equation theory that for any given system of differential equations there is one and only one set of solutions which is zero for negative time, and hence for any dependent variable in the system there is one and only one set of initial derivatives

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1. For all numbered references, see list at end of paper.

difference of potential and the nature of the coolant.

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which satisfy the condition of initial relaxation. We now desire to obtain directly from the differential equation 2 the values of these derivatives of the dependent variable i as t approaches zero from the positive side. In general, if $\phi(p)$ is of the nth degree, it is sufficient to know the initial values of the dependent variable and its first $n-1$ derivatives.

The Procedure

Since we know from the discussion in a preceding section that for an initially relaxed nonimpulsive system all integrals of current and voltage must be zero at $t=0$, it is advantageous to first put the differential equation 2 into integral form by dividing through by p to the highest power found in $\phi(p)$.* It will then be found that by making t and the various integrals $1/p$, $1/p^2$, etc., equal to zero everywhere in the integral equation, the initial value of current, $i(0)$, can be found immediately. Here t is considered to approach zero from the positive side.

To find the initial value of the first derivative of current, $i'(0)$, take the first derivative of the integral equation in a symbolic manner by multiplying through by p, take all indicated derivatives (denoting them by primes where necessary), and again set t and the various integrals $1/p$, $1/p^2$, etc., equal to zero everywhere. Solve for i', which will be di/dt at $t=0$ or $i'(0)$, where t is considered to approach zero from the positive side.

To obtain the initial value of the second derivative, multiply the integral equation through by p^2 and repeat the process. This procedure can be continued indefinitely until the required number of initial derivatives has been found. The process must be a successive one since each derivative will be expressed in terms of lower derivatives.

Since the method requires only the formation of the integral equation and the application of the fact that in an initially relaxed nonimpulsive system the various integrals of current and voltage are zero at $t=0$, it is simpler to apply the process to each problem separately without attempting to derive formulas.

Examples

(1) An A-C Circuit

The differential equations for the circuit shown in figure 1 can be written as:

$$\begin{aligned}(R+1/pC)i_1-(1/pC)i_2&=E\sin\omega t\\(-1/pC)i_1+(1/pC+pL)i_2&=0\end{aligned}\qquad(3)$$

*For a proof of the method, see the appendix.

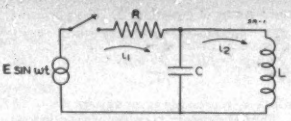

Figure 1. Circuit of example number 1

The elimination of i_2 by algebraic methods yields:

$$\left(RLp^3+\frac{L}{C}p+\frac{R}{C}\right)i_1=\left(Lp^2+\frac{1}{C}\right)E\sin\omega t\quad(4)$$

The steady-state current can be found by the usual complex impedance method:

$$i_{ss}=\frac{E}{|Z|}\sin(\omega t-\phi)$$

where

$$Z=R+j\frac{\omega L}{1-\omega^2LC}$$

and

$$\phi=\tan^{-1}\frac{\omega L}{R(1-\omega^2LC)}$$

If the roots of the characteristic equation $(m^3RL+mL/C+R/C)=0$ are $m=-a_1$, $-a_2$, the total current is given by the expression:

$$i_1=\frac{E}{|Z|}\sin(\omega t-\phi)+C_1\epsilon^{-a_1t}+C_2\epsilon^{-a_2t}\qquad(5)$$

where C_1 and C_2 are the constants of integration to be determined from the initial conditions.

To find the relaxed initial derivatives, return to differential equation 4 and rewrite it as an integral equation by dividing through by p to the highest power found on the left side, p^3. This yields:

$$\left(RL+\frac{L}{C}\frac{1}{p}+\frac{R}{C}\frac{1}{p^3}\right)i=\left(L+\frac{1}{C}\frac{1}{p^2}\right)E\sin\omega t\quad(6)$$

For the initial value of i, set t and the integrals $1/p$ and $1/p^2$ equal to zero in the integral equation 6. Then we have

$$(RL+0+0)i=(L+0)E\sin(0)$$

or

$$i(0)=0$$

For the initial value of di/dt, take the first derivative of the integral equation 6 by multiplying through by p. Then, taking the indicated derivatives and setting t and the various integrals equal to zero, we obtain:

$$RLi'(0)+\frac{L}{C}i(0)+0=LE\omega\cos(0)+0$$

or, since $i(0)=0$,

$$i'(0)=\frac{\omega E}{R}$$

Substituting these two conditions for time $t=0$ into the solution 5 and its first derivative, two equations in terms of the Cs are obtained:

$$C_1+C_2=\frac{E}{|Z|}\sin\phi$$

$$a_1C_1+a_2C_2=\omega E\left[\frac{\cos\phi}{|Z|}-\frac{1}{R}\right]$$

When the equations are solved simultaneously for the Cs, and these substituted into equation 5, the result is the complete solution for an initially relaxed system:

$$i_1=\frac{E}{|Z|}\left[\sin(\omega t-\phi)+\frac{(R\omega\cos\phi-Ra_2\sin\phi-\omega|Z|)\epsilon^{-a_1t}+(Ra_1\sin\phi-R\omega\cos\phi+\omega|Z|)\epsilon^{-a_2t}}{R(a_1-a_2)}\right]$$

(2) Solution of an Oscillatory Circuit

The circuit shown in figure 2 is one in which the initial value of the first derivative of input current is very difficult to find by ordinary means, and where the operational solution becomes rather laborious because of complex quantities which must be rationalized.

The differential equation for the input current can be shown to be:

$$\left[p^2L(R_1+R_2)+p\left(R_1R_2+\frac{L}{C}\right)+\frac{R_1}{C}\right]i=\left(p^2L+pR_2+\frac{1}{C}\right)E\quad(7)$$

If the circuit is oscillatory a convenient form of the solution is:

$$i=\frac{E}{R_1}+\epsilon^{-at}(A\sin\omega t+B\cos\omega t)\qquad(8)$$

where

$$a=\frac{R_1R_2+L/C}{2L(R_1+R_2)}$$

$$\omega=\sqrt{\frac{R_1}{LC(R_1+R_2)}-\frac{(R_1R_2+L/C)^2}{4L^2(R_1+R_2)^2}}$$

To find the successive initial derivatives, first obtain the integral equation by dividing differential equation 7 through by p^3. Set the various integrals equal to zero and obtain

$$[L(R_1+R_2)+0+0]i=(L+0+0)E$$

or

$$i(0)=\frac{E}{R_1+R_2}$$

To find the initial value of the first derivative, multiply the integral equation through by p, take the indicated derivatives, and set the various integrals

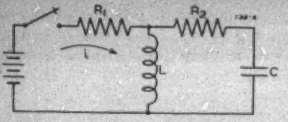

Figure 2. Circuit of example number 2

equal to zero. This yields

$$L(R_1+R_2)i'(0)+(R_1R_2+L/C)i(0)+0=0+R_2E+0$$

and since the value of $i(0)$ has just been found, we can solve for the desired $i'(0)$, obtaining:

$$i'(0)=\frac{E(R_2^2-L/C)}{L(R_1+R_2)^2}$$

If these values of i and i' are substituted into the solution 8 and its first derivative at $t=0$, we find that

$$A=\frac{E}{2\omega L(R_1+R_2)^2}\left[R_2^2-\frac{L}{CR_1}(2R_1+R_2)\right]$$

$$B=\frac{-ER_2}{R_1(R_1+R_2)}$$

The complete solution for relaxed initial conditions can now be written from equation 8 by substitution of these values for A and B. The solution has been obtained in a simple and direct manner, and has avoided a rather laborious manipulation of complex numbers.

Appendix—Proof of Method of Determining Initial Derivatives

Consider the system of differential equations:

$$\sum_{i=1}^{n}(a_{ij}p+b_{ij})x_j=f_i(t),\quad i=1,2\ldots n \tag{9}$$

Let this system be written in terms of continuous variables, for example if current is discontinuous, write the equations in terms of charge. Where second derivatives occur, introduce a new variable z such that:

$$px_j-z_j=0 \tag{10}$$

The second derivative p^2x_j can then be written pz_j, and equation 10 will form part of system 9.

Since the system is linear, the various terms $f(t)$ can be introduced one at a time, and the total solution found by the superposition of the separate solutions. It is therefore sufficient to prove that the method is correct with only one $f(t)$ present. Hence let:

$$\begin{aligned} f_i(t)&=f(t)\quad \text{for } i=1\\ &=0\quad\ \text{for } i\neq 1\end{aligned} \tag{11}$$

First find the initial values of the derivatives of x_k by solving the system of equations 9 for time $t=0$. To do this, transpose the b-terms of equations 9, thus obtaining:

$$\sum_{j=1}^{n}a_{ij}x_j'=f_i(t)-\sum_{j=1}^{n}b_{ij}x_j \tag{12}$$

where x_j' represents px_j or dx_j/dt.

The independent variables are continuous, so $x_j(0+)=0$. Let $t=0$ in equations 12 and solve the system for $x_k'(0+)$. Then:

$$x_k'(0+)=\frac{M_{1k}}{D}f(0+) \tag{13}$$

where D is the determinant of the a's, and M_{1k} is the minor obtained by striking out the first row and kth column of this determinant and attaching the sign $(-1)^{k+1}$.

Differentiate equations 12 once, set $t=0$, substitute equation 13, and solve for $x_k''(0+)$, which is d^2x_k/dt^2 at $t=0+$.

$$x_k''(0+)=\frac{M_{1k}}{D}f'(0+)-\frac{f(0+)}{D^2}\sum_{i=1}^{n}\sum_{j=1}^{n}b_{ij}M_{ik}M_{1j} \tag{14}$$

This process can be continued indefinitely to find the initial values of higher derivatives.

It will now be shown that the same results are obtained by means of the new method. Return to the original system of equations 9 and eliminate all of the dependent variables except x_k. This yields:

$$(A_0p^n+A_1p^{n-1}+\ldots+A_n)x_k=(B_1p^{n-1}+B_2p^{n-2}+\ldots+B_n)f(t) \tag{15}$$

where

$$\begin{aligned} A_0&=D\\ A_1&=\sum_{i=1}^{n}\sum_{j=1}^{n}b_{ij}M_{ij} \qquad\qquad (16)\\ &\vdots\\ B_1&=M_{1k}\\ B_2&=\sum_{i=2}^{n}\sum_{\substack{j=1\\ j\neq k}}^{n}b_{ij}M_{1i,jk}\\ &\vdots\end{aligned}$$

in which $M_{1i,jk}$ represents the second minor of the determinant D obtained by striking out the first and ith rows and the jth and kth columns, and attaching the sign $(-1)^{i+1+j+k}$ for $j>k$ and $(-1)^{i+j+k}$ for $j<k$.

Applying the new method of determining initial values of derivatives to equation 15, we find that:

$$x_k(0+)=0 \tag{17}$$

$$x_k'(0+)=\frac{M_{1k}}{D}f(0+) \tag{18}$$

$$x_k''(0+)=\frac{M_{1k}}{D}f'(0+)+\frac{f(0+)}{D^2}\left[\sum_{i=2}^{n}\sum_{\substack{j=1\\ j\neq k}}^{n}b_{ij}DM_{1i,jk}-\sum_{i=1}^{n}\sum_{j=1}^{n}b_{ij}M_{ij}M_{1k}\right] \tag{19}$$

Equation 17 is correct by virtue of the continuity of the x's, equation 18 checks with equation 13 as obtained by the other method, and comparison of equation 14 with equation 19 shows that the following condition must be satisfied:

$$\sum_{i=1}^{n}\sum_{j=1}^{n}b_{ij}M_{ik}M_{1j}=\sum_{i=1}^{n}\sum_{j=1}^{n}b_{ij}M_{ij}M_{1k}-\sum_{i=2}^{n}\sum_{\substack{j=1\\ j\neq k}}^{n}b_{ij}DM_{1i,jk} \tag{20}$$

The coefficients of the b's must be separately equal. Because of the conditions on the last summation, three cases must be distinguished:

Case I. i=1, j unrestricted

The coefficients of b_{1j} as obtained from equation 20 are:

$$M_{1k}M_{1j}=M_{1j}M_{1k}$$

which is an identity.

Case II. i unrestricted, j=k

The coefficients of b_{ik} in equation 20 are:

$$M_{ik}M_{1k}=M_{ik}M_{1k}$$

Case III. i≠1, j≠k

The coefficients of b_{ij} yield the following relation which must be satisfied:

$$M_{ik}M_{1k}-M_{ik}M_{1j}=D\cdot M_{1i,jk} \tag{21}$$

The left side of equation 21 can be written as an nth order determinant, which, when multiplied by the determinant D rearranged with the former kth and jth columns as the first and second columns, and with the former ith row shifted to the second row, yields the following result:

$$\begin{vmatrix} a_{1k} & a_{1j} & a_{11}\ldots a_{1n}\\ a_{ik} & a_{ij} & a_{i1}\ldots a_{in}\\ a_{2k} & a_{2j} & a_{21}\ldots a_{2n}\\ \vdots & \vdots & \vdots\\ a_{nk} & a_{nj} & a_{n1}\ldots a_{nn}\end{vmatrix}\cdot\begin{vmatrix} M_{1k} & M_{ik} & 0 & 0\ldots 0\\ M_{1j} & M_{ij} & 0 & 0\ldots 0\\ M_{11} & M_{i1} & 1 & 0\ldots 0\\ M_{12} & M_{i2} & 0 & 1\ldots 0\\ \vdots & \vdots & \vdots & \vdots\\ M_{1n} & M_{in} & 0 & 0\ldots 1\end{vmatrix}=\begin{vmatrix} D & 0 & a_{11}\ldots a_{1n}\\ 0 & D & a_{i1}\ldots a_{in}\\ 0 & 0 & a_{21}\ldots a_{2n}\\ \vdots & \vdots & \vdots\\ 0 & 0 & a_{n1}\ldots a_{nn}\end{vmatrix}$$

The left side is equal to $(-1)^{i+j+k+1}D[M_{ij}M_{1k}-M_{ik}M_{1j}]$ for $j>k$ and to $(-1)^{i+j+k}D[M_{ij}M_{1k}-M_{ik}M_{1j}]$ for $j<k$. The right side, when expanded, is found to be equal to $(-1)^{i+j+k+1}D^2\cdot M_{1i,jk}$ for $j>k$ and to $(-1)^{i+j+k}D^2\cdot M_{1i,jk}$ for $j<k$, so therefore:

$$M_{ij}M_{1k}-M_{ik}M_{1j}=D\cdot M_{1i,jk}$$

which was to be proved.

If the differential equation 15 had been written in terms of a variable with a simple discontinuity at $t=0$, say in terms of the first derivative of x_k, each term on the right side of equation 15 would have been raised once in power of p. The method will yield

The Varioplex—a New Development in Telegraphy

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Synopsis: The varioplex method of telegraphic operation provides each pair of stations connected together by it an ever-ready two-way channel for the exchange of traffic, which occupies a band width of zero when idle and of a variable width when busy, depending upon extent of simultaneous usage by other connected stations. It possesses certain advantages over, or in supplement to, other forms of manual and machine switching or repeatering. Adapted to the use of private subscribers through telemeter service, it is finding extensive application in the telegraph plant.

A GOOD deal of current effort in the telegraph engineering field is being directed toward the solution of problems of trunking and switching. Basically, these problems arise from the circumstance that important trunking centers, like Boston, Atlanta, or Los Angeles, have tributary to them most of the less important telegraph offices in their respective surrounding areas. That this is so with respect to the many branch telegraph offices and tie-line connections which dot the larger American cities requires no explanation; the growth of commerce along the railroads has made it no less true of cities and towns many miles from trunking centers. The existence of fanned-out local telegraph circuits around Boston as a hub, to take that city as an example, is inherent in the commercial relationship of most New England towns to its dominating city. It can be appreciated, then, why the Boston office, in years past, has acted not only as the terminal for a considerable day-to-day traffic between Taunton and Boston but also as the relay point for the less frequent messages between Taunton and New York. This situation exists the country over. Of recent years, improvements in the transmission qualities of these tributary circuits have made it possible to terminate them, almost universally, in printing telegraph equipment.

Between the larger cities for years there have existed the more heavily loaded trunk wires, over which has flowed traffic manually fed to them by the tributary networks. Through the use of synchronously-operating multiplex distributors, the capacity of these intercity trunk facilities has been made conveniently divisible into units called traffic channels, of an output adapted to the capabilities of operators. These channels operate at speeds of from 60 to 75 words per minute. The gradual standardization of printer equipment, the stabilization of unit capacities, and the adaptability of printer circuits to end-on repeatering have together extended an open invitation to engineers to increase the number of trunk channels regularly connected, or temporarily connected on demand, to other trunk channels and to fanned-out tributary trunks and tie lines, thus markedly increasing the number of pairs of cities, pairs of towns, of branch offices, and of customers, directly tied together by traffic channels.

In creating such through channels between distant terminals, recourse has been had to end-on switching of a variety of types of circuit constituting the intervening geographical circuit sections. Some have been of start-stop, others of the multiplex time-division, or sector, type; some have been routed over duplexed ground-return physical conductors, others over metallic loops, or over composite or superimposed d-c pairs, or over a-c carriers; and either with or without electromechanical storage en route.

The type of switching adopted for increasing the length and number of these standard-width traffic channels has been influenced in part by the holding time of the connections. Where day-by-day connection of intercity trunks has been desirable, fork-series connection of multiplex channels,[1] and extended start-stop channels,[2] have produced efficient results. Where telegraph-talk connections have had to be quickly set up and pulled down[3] in a manner similar to that employed in connecting long-distance telephone calls, the general pattern of toll switching[4] has been followed. Where the bulk of the traffic is single-shot, forms of dial machine switching[5] have proved advantageous. In the admixture of all types of traffic in a large office installation, the manual switching of reperforators[6] has been successful. All these methods have been, and still are, significant in telegraphy as it is being developed in the United States today.

The Varioplex Concept

Whatever the form of switching, switched telegraph channels, up until the present time, have had in common the characteristic of occupying a frequency band of constant width, whether busy or idle. Although not standardized, such bands have been of the order of 20 cycles per second in width, accommodating traffic at a rate, representatively, of 65 words a minute.

Against the foregoing background of progress, Philo Holcomb, Jr., the author of a companion paper[7] before this convention, originally projected the concept of, and devised the circuits for, a telegraphic "lane" for traffic, of variable, rather than of constant, width—a lane whose width occupied the full capacity of a geographical circuit section at times when that lane alone was being accommodated—a lane whose width adjusted itself automatically to occupy only its proportionate share of a component circuit section at times when that circuit section was simultaneously accommodating other lanes of traffic—and, most important of all, a lane for traffic whose

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1. For all numbered references, see list at end of paper.

the proper initial values in this case also, for the initial value of the new variable will be equal to the first derivative of the old, and so on. The method is therefore applicable to variables with a simple discontinuity at $t=0$, as well as to variables which are continuous everywhere.

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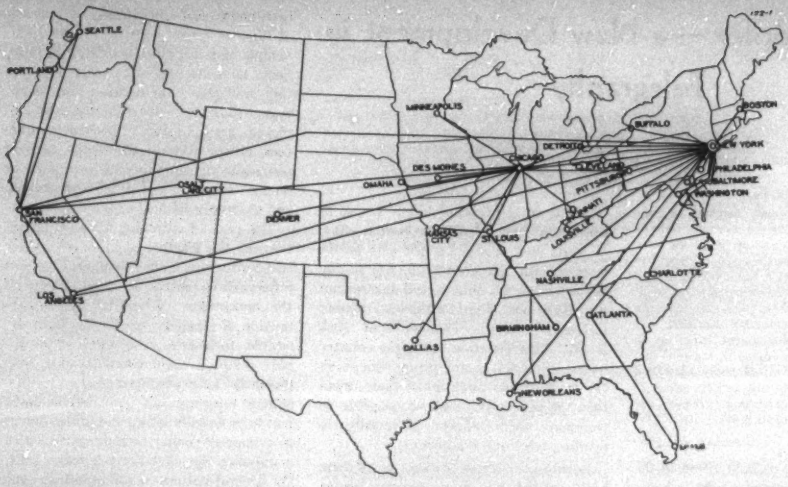

Figure 1. Map of varioplex systems in United States

width decreased to zero, automatically, whenever no traffic happened to be passing over the lane.

It was at once obvious that with such an expanding, contracting, variable-width lane, it would be practicable, ultimately, to set up a multiplicity of direct connections theretofore considered out of the question because of light loads. For the lane width now having been reduced to zero when idle, there remained no necessity to deny to two telegraph offices or to two tie-line customers or subscribers a direct lane for traffic merely because the load offered happened to be small in relation to the total capacity of a 20-cycle-per-second channel of multiplex over which it might be switched.

An important part of the concept was that the effect of switching thus secured was to be accomplished, not manually as by a plug-and-jack switchboard, nor automatically as by dialing a number, but by the expedient of providing that the two terminals should always remain interconnected through the system but completely "inert" until traffic was offered. The fundamental switched informational unit was to be, not the duration of a toll call, not the length of a series of messages or even of one telegram, but the amount of information transmitted by the operator without pause, be that the extreme length of a press dispatch or, at the other extreme, the length of one word, a numeral, or even a solitary letter.

Applications

The original concepts and circuits were developed by the Western Union engineering department and the systems given the name of varioplex. The map, figure 1, shows the extent of application of such systems, and the photograph, figure 2, depicts the installation of 4 out of the 16 systems terminating in the main telegraph office in New York City. The 39 systems operate over 92 channels of standard duplex multiplexing equipment and provide 736 unidirectional lanes, or 368 two-directional "subchannels" as they are referred to, of communication.

A typical varioplex system is that set up between Los Angeles and San Francisco, consisting of 27 subchannels. Twenty-two of the 27 subchannels provide direct two-way printer operation between 22 pairs of San Francisco and Los Angeles branch offices or subscribers' tie lines, the business between which hitherto would have had to be carried on 22 individual wires or manually relayed in San Francisco and again in Los Angeles. The remaining five subchannels provide Los Angeles Western Union with direct connection to offices in Seattle, Chicago, Sacramento, Oakland, and Reno, through flexible linkage at San Francisco. In the case of the Seattle connection, the Los Angeles-San Francisco varioplex subchannel is connected to a San Francisco-Seattle varioplex subchannel; a similar connection is made at San Francisco on a varioplex subchannel going through to Chicago. In the case of Sacramento and Oakland, physical wires carrying start-stop teleprinter signals between those cities and San Francisco are repeatered separately at San Francisco into the two varioplex subchannels to Los Angeles. In the case of Reno, a multiplex channel

Figure 2. Four of 16 systems of varioplex apparatus in New York main office

between Reno and San Francisco is coupled to the Los Angeles varioplex subchannel at San Francisco.

Capacity

Sixty-six words per minute has been adopted as the standard multiplex channel speed for varioplex systems. The total capacities of such systems are, therefore, 66, 132, 198, and 264 words per minute in each direction, depending upon whether the varioplex system is carried over one, two, three, or four channels of multiplex. The Los Angeles-San Francisco system referred to is of 264 words capacity.

Some idea of the flexibility of varioplex systems may be gained by consideration of the equipment of three multiplex channels on a physical wire (or two unidirectional channels of audio-frequency telegraph carrier) between New York and St. Louis. One of the channels is retained in use as a duplex printer trunk; the second carries a three-subchannel varioplex system; the third carries a six-subchannel varioplex. By way of comparison, the Chicago-Los Angeles varioplex of six subchannels occupies the combined capacity of all three multiplex channels.

The type of varioplex system chosen and the number, type, and traffic loading of the subchannels assigned to it, are matters tied up with the time, frequency, and duration of the occurrence of peaks of simultaneous demand for facilities. The maximum number of subchannels now assigned to a varioplex system in service is 36. It is thought that this figure by no means represents the upper limit of lightly loaded subchannels which ultimately will economically be so assigned. If all 36, or all 48, 99, or whatever the upper limit may prove to be—if all the connected load were to demand simultaneous use of the circuit, the speed per channel would be very low indeed, the total to be divided among all being only, say, 264 words per minute. In practice, however, the maximum simultaneous demand has been recorded at only nine subchannels on this 36 subchannel system; each channel was operating at 29 words per minute during the period of maximum demand. The usual condition of simultaneous demand has been found to lie between two and five channels on this 36 subchannel system. Since all subchannels enjoy full speed of 66 words per minute on this circuit until the fifth subchannel cuts in, it may be said that only occasionally is the speed ever reduced from that figure, and in such cases only down to 53 words per minute for brief intervals.

When, because too large a number of varioplex subchannels are in simultaneous use their respective speeds are unreasonably low, the obvious cure is to reassign the subchannels. Examination into the causes of abnormal simultaneous usage has often pointed the way to corrective action. Low subchannel speed is not a defect of the varioplexing process, for the situation on the superseded multiplex under the conditions of manual operation and with the same concentrated fall of traffic would be even worse. For a given fall of traffic the varioplex packs the informational content more compactly into the available transmission band width than does any other form of telegraphy. If a multiplex circuit between New York and Seattle has a capacity of 100 messages per hour and satisfactorily handles all the traffic on a manual-relay basis between the New York and Seattle areas, experience has pointed to the conclusion that all the offices in those areas could, if desired, be interconnected by varioplex over the long haul and there would be no excessive demand peak, and no unreasonably low channel speeds would be encountered. In fact, it would be found that more offices and more traffic could be added to the connected load without encountering trouble.

Occasional reduction of speed is noticeable to a receiving operator watching a printer working on a varioplex subchannel. From the viewpoint of the sending operator, however, there is no difference between varioplex and teleprinter transmission. The line from the sending printer on each operating table is connected to an individual distributor and automatic perforator combination at the varioplex terminal, shown in figure 3. This combination converts the seven unit start-stop signals from the sending printer keyboard to a perforated paper tape in the usual five-unit multiplex code. The sending line and distributor-perforator combination are continuously available to the operating table so that the sending operator may send at any time at the full teleprinter speed of 65 words per minute. Thus is met the requirement of a continuously available full-speed channel for the transmission of traffic from the operating position. Regardless of the speed variations that may exist in transmitting the characters over the trunk channels, the full capacity and efficiency of the sending operator may be utilized whenever traffic is on hand for transmission.

Advantages

Regardless of the extent to which the varioplex has already been installed, its full potentialities in increasing the efficiency of utilization of trunk circuits and equipment may not yet have been fully realized. A telegraph informational transmission band is essentially very narrow—of the order of 20 cycles per second or less, as pointed out before. To assign a physical wire to its transmission is an unconscionable waste from an engineer's standpoint. To assign to it a carrier with comparatively wide intercarrier spacing is only slightly more pardonable. Interlocking multiplexed channels are more efficient as to band width occupied, but even here the fixed width of each of the channels admits of no conformation either to the human limitations of the operators or to the vagaries of the fall of traffic. Surveys of trunk groups with a mixture of physical, derived, and carrier circuits employed in diverse services have shown an unused capacity as high as 70 per cent on facilities considered "full." Divided into units of capacity of 60 to 70 words per minute, there were, literally, no facilities to be spared in the groups under survey. Only by varioplexing all facilities in such circuit groups can 100 per cent utilization be approached. One great contribution of the varioplex to the telegraph art is that its flexibility makes available for traffic many of the heretofore idle cracks and corners of the telegraph wire-plant capacity.

A second important advantage of the varioplex is that no matter how heavily congested one or more of the circuit sections may be over which the lane for traffic is connected, transmission of the first character of every message initiated is started immediately and completed forthwith, from origin to destination, as soon as the keyboard is manipulated. There is no testing for idle channels, no busy signals are received, no time is wasted in handling dial-switching impulses, there is no additive delay due to such impulses traversing the chain of connection, no waiting for a particularly long message to clear out of the way. Since all varioplex connections are, in essence, perpetually connected two-way circuits, there is no waiting involved on the part of the sending office for a quick acknowledgment of receipt on the part of the receiving office.

A third major advantage which the varioplex contributes to the art is the compounding of possibilities of elimination of manual relaying of telegraphic information. While other modern meth-

Figure 3. Racks containing equipment for nine type C varioplex subchannels

ods of switching channels accomplish a similar purpose, their scope has been limited by the requirement that, to justify economical switching, the switched informational unit must contain a practical minimum number of words. Elimination of such an economic minimum through the varioplex principle throws open a wide field of development for switching, with all its demonstrated advantages over manual relaying. The number of operations and the amount of supervision are reduced—so are investment, operating maintenance, and inspection costs of belt conveyors, branch-office pneumatic tubes, printers, perforators, typewriters, and stationery. So too are routing and servicing costs cut down. Because varioplex repeaters require much less room than corresponding channels for manual relaying, there are additional savings in rental items.

A fourth advantage of the varioplex is, in a sense, a derivative of the other three in their application to the use of public telegraph facilities by private communication systems. By employing varioplex subchannels, users need no longer choose between the continuous utilization of a full standard-width communication channel on the one hand and a discontinuous service on the other. Varioplex connections between two private customers afford them teleprinter intercommunication at any time without the necessity of ordering a circuit to be made up and without any impulse to hurry or terminate a conversation through lapse of time alone. Opportunity is thus afforded for deliberation between questions and answers and for consulting files, assistants, and authorities. To utilize a varioplex subchannel for this type of service it is necessary only to present a sufficient volume of traffic to pay the costs of providing the subchannel equipment; the charge may then be based on volume rates for the traffic actually handled. A metering instrument incorporating a character counter has been developed for such an application, and the varioplex facility is now widely used by subscribers under the name of telemeter service.

Conclusion

The increase in the efficiency of utilization of trunk-circuit capacity effected by the use of varioplex equipment is an obvious and worth-while contribution to telegraph progress. The dissociation of subchannels for point-to-point communication from the use of trunk-circuit capacity except when traffic is actually being transmitted is reflected in a greater return on investment in lines and terminal equipment. In laying out point-to-point channels for the handling of commercial telegraph traffic operating engineers need no longer be bound by former limitations as to traffic volumes. To establish a direct channel of communication, a volume of traffic sufficient to justify the use of a fixed amount of trunk-circuit capacity represented by at least one full trunk channel has in the past been necessary. Assuming that the total traffic between the areas concerned justifies the use of varioplex equipment as many individual subchannels as needed can be set up, it being necessary for the loads on these individual subchannels to be sufficient to justify only the subchannel operating equipment and the equipment for connecting it into the varioplex system. This possibility is further multiplied through the interconnection of subchannels from two or more systems to effect direct connections between areas not directly served by individual varioplex systems.

Experience is now beginning to reveal the optimum economic usage of methods of machine-switching, reperforation, and varioplex. Many interesting combinations are possible. Long-haul, intercity varioplex channels may be dialed by various branch offices in the city of origin, and fanned out by manually-switched reperforators in the cities of destination. Thus is indicated a material increase in the number of direct connections between telegraph offices and a resulting better telegraph service to the American public.

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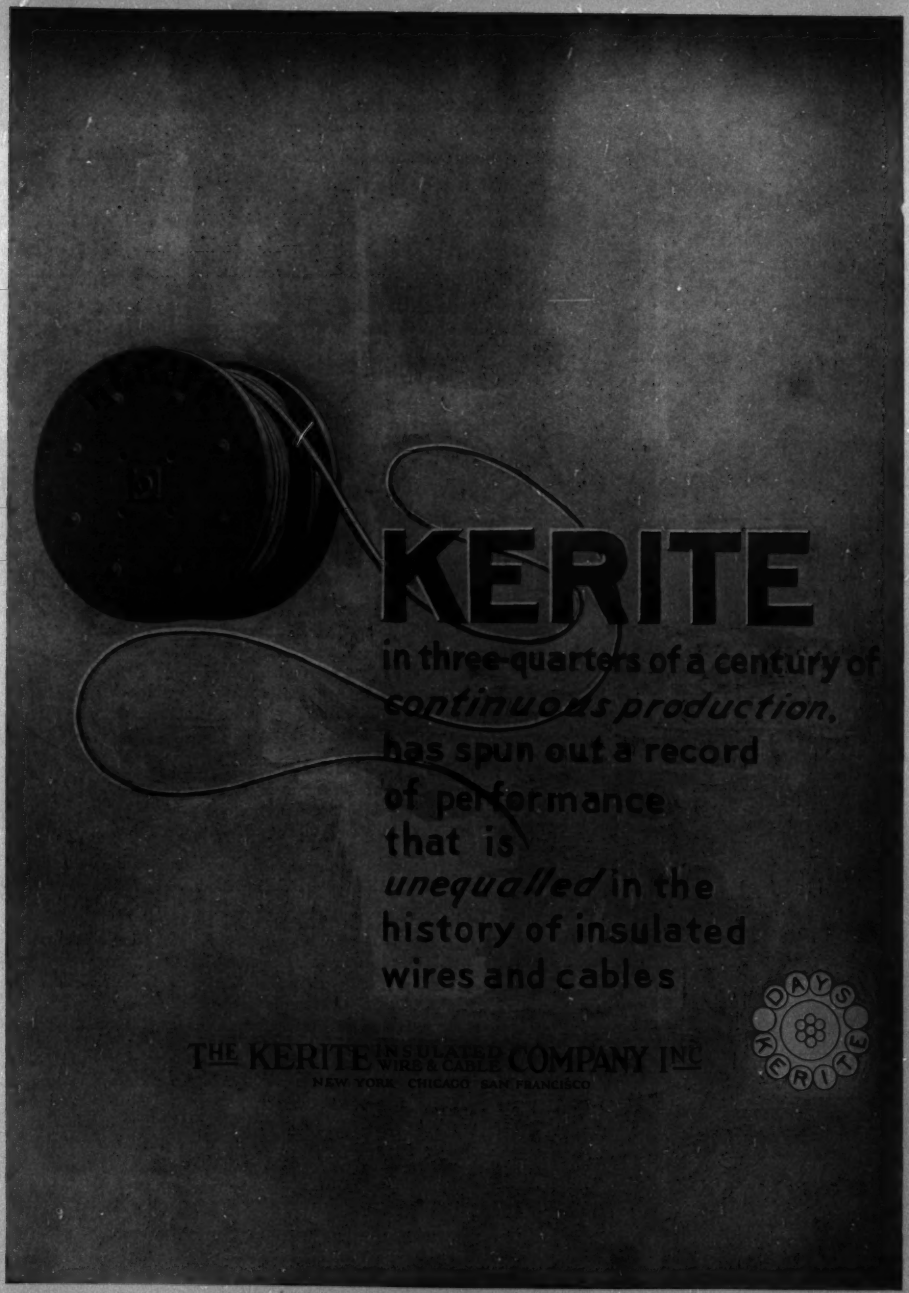
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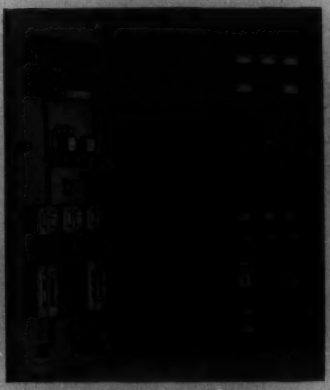

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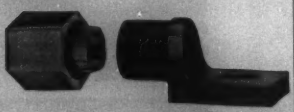

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(Continued on page 14)

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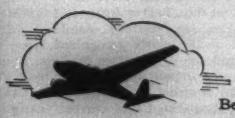

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FROM 23 KV TO 115 KV

WITH THESE CHARACTERISTICS:

Pyranol for Safety

Accuracy ¼W, ¼X, ¼Y, ¼Z

Small Size—Light Weight

Insulation to Meet ASA Standards

For further information write to the nearest G-E office, or to General Electric Company, Schenectady, N.Y.

GENERAL ELECTRIC

ANOTHER WAY ELECTRICAL POWER IS SPEEDING PRODUCTION

MORE PLANE PARTS PER DAY

Because Westinghouse Developed a Furnace

Normally when steel is heat-treated it undergoes a form of surface deterioration called "decarburization." Correcting this defect takes time . . . slows down production.

Westinghouse solved this production problem with a new type of furnace . . . a furnace with an "Endogas" atmosphere that delivers heat-treated parts with bright, clean surfaces . . . parts that need a minimum of finishing . . . in many cases none at all.

This development has made possible the production of more airplane engine parts per day.

The furnace itself requires no expensive accessories . . . is simple to operate . . . easy to install. The newly developed "Endogas" atmosphere, which is produced from ordinary city fuel gas, can be used for the treatment of all SAE steels. Proof of results is found in reports like this:—"In one shift we hardened 20,000 small alloy bolts. This would have taken a week in our old furnace, with the added cost and delay of pickling."

Your production problem may not be that of hardening steel. But remember, Westinghouse maintains a corps of engineers whose entire time is devoted to solving production problems for industry. Their job is to help you. Use their services freely.

Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Westinghouse

Time-Saver For American Industry

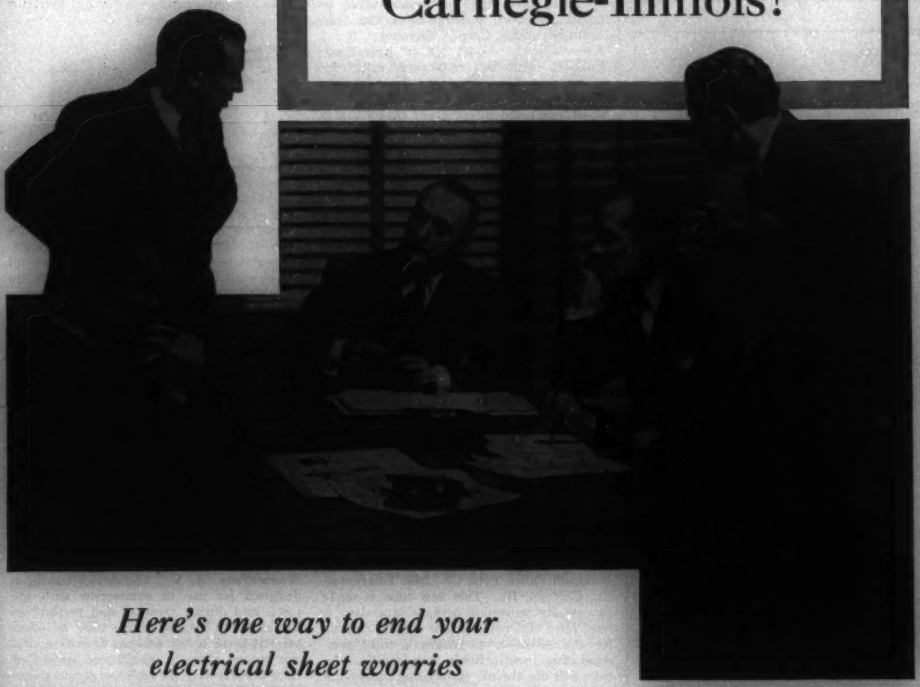
ELECTRICAL POWER SPEEDS PRODUCTION

No American manufacturer can afford to overlook the modern methods and equipment offered by the electrical industry for speeding up production. A phone call will bring a Westinghouse representative to your office to discuss your problems.

Future advertisements on this page will describe how Westinghouse is helping in the mining . . . steel . . . metal-working . . . textile . . . marine . . . and other industries. Watch for these stories.

J-94419

"Why not ask Carnegie-Illinois?"



Here's one way to end your electrical sheet worries

OVER 37 years ago the first silicon steel sheets for electrical use were produced in our Vandergrift plant. Since then we have accumulated a wealth of experience in the manufacture and use of electrical sheets, which we offer to the manufacturers of electrical equipment.

Today, Carnegie-Illinois makes available the services of a trained staff of electrical sheet specialists. These men know which sheet grade will give the best performance, the right electrical properties — how to specify the proper grade and the most economical size to use.

Why not call in the man from Carnegie-Illinois when you have problems involving the use of electrical sheets? It won't cost you a cent. Many manufacturers have found it worth while in lowering production costs and increasing efficiency of equipment.

USS

ELECTRICAL STEEL SHEETS

for motors, generators and transformers

CARNEGIE-ILLINOIS STEEL CORPORATION

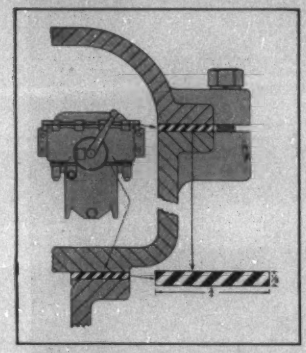
Pittsburgh and Chicago

Columbia Steel Company, San Francisco, *Pacific Coast Distributors* · Scully Steel Products Company, Chicago, *Warehouse Distributors*
United States Steel Export Company, New York

UNITED STATES STEEL

PROBLEM: To seal an oil-filled circuit breaker for use in subways where total submersion in water may occur

SOLUTION: Compressible gaskets of Armstrong's Corprene DC-100



A MANUFACTURER of oil-filled circuit breakers and switches had difficulty in securing *tight* gasketed joints. Used in subways and manholes, his equipment was often completely submerged in water. Rubber-like synthetic materials were tried which resisted the attack of oil and water. However, since restraining devices could not be used, the gaskets tended to flow or extrude when bolts were drawn down tight enough to seal all unevenness in the flanges. This resulted in severe leakage.

How Leakage Was Stopped

Then Corprene DC-100 was tried. It completely resisted the penetration of oil and water—and their destructive effects. Being truly compressible, the Corprene gaskets were drawn down to two thirds of their original thickness with no tendency to flow or extrude. This one third compression permitted effective sealing of all flanges, and all units passed acceptance tests of five pounds internal air pressure while totally immersed in water. In service, no leakage has occurred.

What Is Corprene?

"Corprene" is the trade name for a group of more than two dozen cork-and-synthetic-rubber compositions—made in sheets, cut pieces, and molded forms. The unique feature of Corprene lies in the fact that its physical properties can be "tailor-made" to meet your requirements. Its compressibility, lateral flow, chemical and solvent resistance, coefficient of friction, hardness, and tensile strength can be controlled within narrow limits. That's why millions of Corprene gaskets and packings are now licking tough sealing problems in modern equipment.

Whenever *you* have a tough sealing problem, remember—Corprene can probably solve it for you. Get all the facts now about this versatile material. Write today to Armstrong Cork Company, Industrial Division, 943 Arch St., Lancaster, Pa.

ARMSTRONG'S *Corprene*

COMPOSITIONS OF CORK AND RUBBER-LIKE MATERIALS

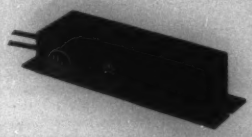
New Products

Capacitor Analyzer.—A new, "quick-check" capacitor analyzer that affords most complete qualitative or quantitative reports, has been developed by the Solar Manufacturing Corp., Bayonne, N. J. Known as the model "QCA" it indicates leakage, insulation resistance, radio frequency impedance, power factor, capacities, and in addition affords a dynamic check for short, open and intermittent circuits. The instrument operates equally well whether

the condenser is fully connected in the circuit, or has one or both leads disconnected, or even if the condenser is shunted by an inductance or resistance. Two styles are available: portable models or units for service bench mounting.

Transparent Acetate Tube.—A new self-supporting, spirally wound, transparent acetate tube has been introduced by the Precision Paper Tube Co., 2033 Charleston St., Chicago, Ill. This new tube is made by spirally wrapping acetate tape over a steel form and using a new acetate cement for the adhesive to insure a solid non-separating wall. Being pre-formed, the tube will not shrink, eliminating one of the difficulties found in extruded acetate tubes. This new product is supplied in continuous lengths of any wall thickness with any inside or outside diameter. Due to its superior dielectric properties, it is applicable to many high frequency and electronic applications and for certain types and applications of low amperage cartridge fuses. Being highly transparent, not easily broken, and having a low moisture absorption rate, it has been suggested for liquid gauges where temperatures do not exceed 180 degrees Fahrenheit.

Fluorescent Fixture Resistors.—Type FL resistors, specifically designed in small size with low temperature rise for d-c operation



of fluorescent lamps, and listed under the Underwriters Laboratory Re-examination Service, have been introduced in a complete line of voltages and sizes to fit all standard wiring strips by the International Resistance Co., 427 North Broad St., Philadelphia, Pa. The resistance units are of the wire wound type, with full molded 1250-volt insulation topped by a metal strip to aid in heat dissipation. These resistors are enclosed in low metal boxes of special ventilated construction and sufficiently small to fit in the fixture channel. The units operate at a temperature rise of from approximately 40 to 50 degrees Centigrade with standard auxiliaries. Overall box dimensions are approximately $6^{3}/_{8}$ by $1^{3}/_{4}$ by $1^{1}/_{4}$ inches, and the total assembled weight is less than 12 ounces.

Recording A-C Bridge.—An alternating-current bridge for rapid recording of changes in cable, capacitors, and insulating materials undergoing deterioration tests has been developed by the General Electric Co., Schenectady, N. Y. The device has been designed for use in connection with life tests, and during treating and production processes. The new bridge may be operated 24 hours a day without attention, and can record changes within one second of their occurrence. In addition to a conven-

(Continued on page 24)

Fiberglas* Insulation cut losses from downtime on the toughest jobs

LAST YEAR a certain Midwestern steel plant changed over to Fiberglas for electrical insulation.

Result: $24,000 saved on maintenance (according to the company's own figures).

In addition, *they had less downtime* on equipment that worked in moisture...

. . . in scorching heat, dust, flying scale-particles from the rolling mills . . . over pickling baths where corrosive acid fumes surround the motors . . . and on cranes where many stops and starts cause serious overloads.

What's more, the company made that $24,000 saving even though they had *more* equipment running *more* hours than the previous year!

Wherever you have tough jobs to do, Fiberglas may well do them better, with fewer headaches, and at less cost.

Perhaps you don't have motors working under tough conditions. Perhaps the surroundings in which your motors work are entirely normal.

Then so what?

Is it possible for Fiberglas-insulated motors to help you?

Yes! *And in a very important way!*

Today, industry is gearing up for defense production. 24-hour schedules are becoming more and more common. And as machinery operates more hours per day and at greater speeds, *the hazard of downtime mounts.*

You need an additional safety factor in your motors. And you can get the maximum safety factor in standard-size Fiberglas-insulated motors.

Also, today important motor manufacturers are making smaller-size Fiberglas-insulated motors which operate safely at approved higher temperatures.

And the pay-off?

Even these smaller motors have a substantially larger safety factor than ordinary motors insulated with class A materials. And their cost is little, if any, more.

So, with the expensive bugaboo of downtime looming larger on the industrial horizon, watch out! In new equipment or in your next repair job, specify complete Fiberglas Electrical Insulation. *Owens-Corning Fiberglas Corporation, Toledo, O. In Canada: Fiberglas Canada, Ltd., Oshawa, Ont.*

OWENS-CORNING

FIBERGLAS*

*T. M. Reg. U. S. Pat. Off.

TO ELECTRICAL ENGINEERS: Besides being a superior insulation for motors and generators, as the above case history shows, we believe you will find Fiberglas has definite advantages for all types of electrical equipment. This insulation comes in all standard forms. Write us for further technical data.

•CAPACITORS•

Write for Your Copy...

● Here's the combined manual and catalog on motor capacitors. Just the practical data you need on motor capacitors—diagrams, charts, formulas, *plus* complete handy listings on all standard capacitor-start motors and their capacitor requirements. Handy cross-index of Aerovox capacitors and motor manufacturers' part numbers. ● Write us for your copy. ● Submit that motor-capacitor problem for our engineering collaboration.

AEROVOX CORPORATION
NEW BEDFORD, MASS.
IN CANADA: AEROVOX CANADA Limited, Hamilton, Ont.

INSULATOR **Headquarters**

If you want highest quality insulators to match the outstanding performance of your product, then bring your problems to Universal, headquarters for quality insulators.

Special or standard shapes. Made by the famous Universal "dry process." Better thruout. Close dimension tolerances. Send your specifications for sample and price.

THE UNIVERSAL
1560 EAST FIRST ST.

CLAY PRODUCTS CO.
SANDUSKY • OHIO

NOTHING TAKES THE SHOCK LIKE RUBBER

. . . THAT'S WHY THIS DIRECT DRIVE COUPLING IMPROVES PERFORMANCE OF RESILIENTLY MOUNTED MOTORS

Features rubber cushion, made with exclusive oil-resisting treatment. Gripped permanently by die-cast ends.

Custom-made in various degrees of flexibility, engineered to job. Splined sleeve or standard types. Made any length from 2-1/2" up. Bores 5/16", 3/8", 7/16" and 1/2". Amazingly simple construction. No parts to get out of order, become noisy, or need replacement. More than a half million in service.

SAMPLE FOR TESTING ON REQUEST

GUARDIAN FLEXIBLE COUPLINGS
214 E. MICHIGAN ST.
MICHIGAN CITY, IND.

OVER 60 CORE SIZES
to meet your exact needs

OHMITE RESISTORS

Sizes from 2½" diam. x 20" long to 5/16" diam. x 1' long—on hand and ready to be made into the exact resistors you require. Also thousands of completely finished resistors carried in stock for immediate shipment.

Write for Ohmite Industrial Catalog No. 40.

OHMITE MANUFACTURING CO.
4801 Flournoy Street ★ Chicago, U.S.A.

Be Right with OHMITE
RHEOSTATS · RESISTORS · TAP SWITCHES

RECOMMENDED PRACTISE FOR ELECTRICAL INSTALLATIONS ON SHIPBOARD

(MARINE RULES)

Section No. 45, AIEE Standards

(*With Addenda as of March 1941*)

THE latest edition of "Recommended Practise for Electrical Installations on Shipboard" (Marine Rules) is published as Section 45 of the AIEE Standards. The pamphlet contains 100 pages; price is $1.50 (50% discount to members of the AIEE).

These rules have been drawn up to serve as a guide for the equipment of merchant ships with electrical apparatus for lighting, signaling, communication, power and propulsion for both alternating and direct current systems. They indicate what is considered good engineering practise with reference to safety of the personnel and of the ship itself, as well as reliability and durability of the electrical apparatus.

American Institute of Electrical Engineers
33 West 39th Street, New York

Stroboscopic F-L-A-S-H Pictures

THE MOTION of many mechanical phenomena which are not cyclic, repetitive or reciprocating can be studied most readily by means of single-flash stroboscopic photographs. Many persons have found the General Radio STROBOTAC and STROBOLUX, which are equipped to operate at single flashes, very useful for taking single-flash photographs when the area to be illuminated is relatively small.

The STROBOTAC-STROBOLUX when connected for single-flash operation provide a powerful flash of about 1/30,000th second duration. The intensity of this flash is high enough to take excellent single-flash pictures with the simplest camera equipment.

The photograph above at the left was taken with ordinary lighting. It represents a Pelton wheel in operation. At the right the same wheel was photographed with a single flash from the STROBOTAC-STROBOLUX. Note how effectively the water jet, the individual particles of water and the buckets on the Pelton wheel have been stopped.

When viewed visually, due to the non-uniform motion of the water drops, it is quite difficult to visualize the exact water column formation; with a single-flash picture the complete story is evident immediately.

Single-flash photography with the General Radio STROBOTAC and STROBOLUX is really quite simple. Little practical photographic experience is required. The additional equipment needed is high-speed film, almost any type of camera and some simple means of synchronizing the flash with the shutter.

Let us tell you more about the interesting possibilities of stroboscopic photography in industry.

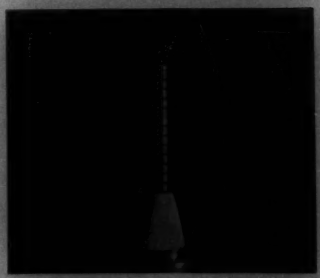
• *WRITE FOR BULLETIN 691*

GENERAL RADIO COMPANY

Cambridge, Massachusetts

Shuttle of a loom being thrown 900 feet a minute

Studying the throw of a switch



This textile spindle was revolving at 10,000 rpm when the single-flash picture was taken

FLUCTUATING LINE VOLTAGE

CONSTANT VOLTAGE

Above 200 VA.

From 20-200 VA.

Up to 15 VA.

Whether it's 1 VA for an instrument or 10 KVA for a production line—here's constant, stable voltage for you at all times, even though the line voltage varies **as much as thirty percent.**

They are fully automatic and instantaneous in operation—have no moving parts—require no maintenance—and are self-protecting against short circuit.

You can build a SOLA CONSTANT VOLTAGE TRANSFORMER into your product, or incorporate it in your production line or laboratory and know that every test will be made under identical line conditions.

Compact—economical. Standard designs are available, or units can be built to your special specifications.

Ask for BULLETIN ACV-74

SOLA ELECTRIC COMPANY
2525 Clybourn Ave. Chicago, Ill.

SOLA

Constant Voltage TRANSFORMERS

A.C. & D.C. • A.C. & D.C.

The Only one for measuring both A.C. and D.C.

That's right, there is only one clamp-type ammeter which measures both A. C. and D. C.—the double-duty TONG TEST. Do your current measuring in less time, with one instrument and save the difference.

TONG TEST is accurate and absolutely safe; it measures currents up to 800 amperes without breaking the circuit and weighs only 3¾ pounds. Low in price, but precision-built, a 2-in-1 TONG TEST quickly pays for itself. All sizes are available from stock.

For complete facts about the TONG TEST, send for the TONG TEST bulletin, today.

Columbia Electric Mfg. Co.
4525 Hamilton Ave. Cleveland, O.

TONG TEST
THE ONLY CLAMP-TYPE A. C. & D. C. AMMETER

A.C. & D.C.

Four New AIEE STANDARDS

Proposed Revisions

•

No. 21—Apparatus Bushings

This proposed standard is issued for purposes of information and criticism. It covers the following types of bushings: (a) outdoor bushings for large apparatus; (b) cover-type bushings for small apparatus; (c) indoor bushings for all types of apparatus except dry-type instrument transformers, air-blast transformers, dry-type regulator, and circuit breakers rated below 5,000 volts, and non-oil-tight oil circuit breakers rated 50,000 kva or less. The bushing requirements as specified will apply to bushings when mounted for testing in accordance with specified arrangements given in the Test Code which is included as an Appendix to the proposed Standard. . . . . No charge.

•

No. 27A—Switchgear Assemblies

A proposed revision of AIEE Standard No. 27 covering assemblies of switchgear devices such as switches, interrupting devices, control, metering, protective and regulating equipment with associated interconnections and supporting structures. This proposed standard does not apply to industrial control equipment, communication switchboards and switching equipment or switchboards for shipboard. . . No charge.

•

No. C37.4 thru C37.9—A-C Power Circuit Breakers

A proposed revision of AIEE Standard No. 19 applying to all indoor and outdoor types of a-c power circuit breakers rated in excess of 600 volts. There is included proposed "American Recommended Practises" and "Test Code for Oil Circuit Breakers." . . . . . Price 60 cents (no discount).

•

No. 41A—Insulator Tests

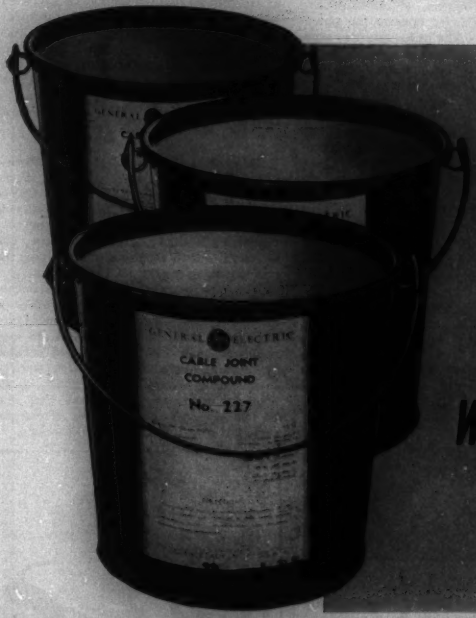
A proposed revision of AIEE Standard No. 41. These proposed standards are not insulator specifications, but comprise a manual of test procedures to be followed in making tests to determine the characteristics of insulators to be used on electric power systems. The standards do not deal with the methods, equipment and technique to be used in making high-voltage measurements. . . . . No charge.

•

American Institute of Electrical Engineers

33 West 39th St. New York, N. Y.

WHERE AND WHY CENTRAL STATIONS USE G-E 227 SEALING AND FILLING COMPOUND



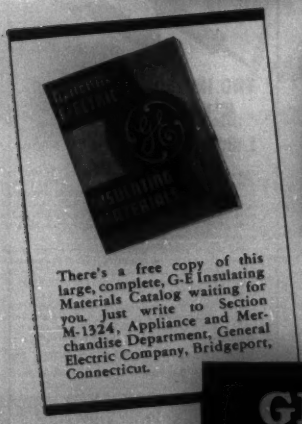
WHERE

- For filling cable end bells
- For filling cable joints
- For filling coupler sockets
- For filling potheads

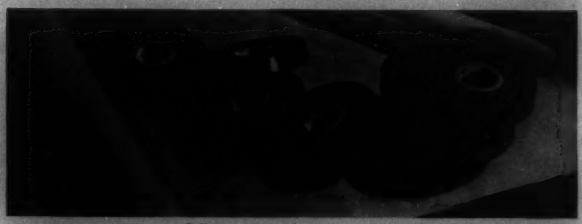
WHY

Because----------

- It flows easily and smoothly at the recommended heating temperature.
- It's highly resistant to moisture.
- It has a high dielectric strength.
- The balance doesn't deteriorate between heatings.
- It remains semi-plastic where it's poured and is easy to remove if necessary.



There's a free copy of this large, complete, G-E Insulating Materials Catalog waiting for you. Just write to Section M-1324, Appliance and Merchandise Department, General Electric Company, Bridgeport, Connecticut.



G-E 992 Varnished Cloth Tape

This tape is easy to work with because it's so flexible. It gives maximum insulating protection due to its high dielectric strength. G-E 992 Tape is moisture- and age-resistant. These qualities mean longer trouble-free operation to you on jobs where this tape is used.

GENERAL ELECTRIC

Select the
OSCILLOGRAPH
that best fits
YOUR JOB

★ Here are three of the several types of DuMont cathode-ray oscillographs that give you a wide choice in selecting that instrument best fitted to your needs:

Type 184: An exceptionally compact, portable and inexpensive 3-inch instrument, ideally suited to production testing. Incorporates a vertical amplifier with voltage gain of 70 times, and a horizontal amplifier with voltage gain of 40 times, over the frequency range from 15 to 30,000 sinusoidal cycles per second. Horizontal amplifier amplifies either the sweep circuit or any external signal. Deflection plate terminals externally available.

Type 188: Moderately-priced 5-inch oscillograph. Larger screen size makes it ideal for studies requiring greater definition, particularly for lecture demonstration work. Vertical amplifier has voltage gain of 450 times. Input signal may be connected to either the amplifier input or to deflection plates, at front panel. Sweep circuit has a repetition rate of 15-30,000 times per second.

Type 208: Incorporates many desirable improvements and refinements, making it ideal laboratory oscillograph. Utilizes the DuMont intensifier-type cathode-ray tube with four deflection plates for use with balanced signal circuits. Vertical amplifier has voltage gain of 2000 times over a frequency range of 2 to 100,000 sinusoidal cycles per second. Linear time base has a repetition rate variable from 5 to 50,000 times per second. Instantaneous position control. Regulated power supply.

Write for Data...

★ Information on these and other DuMont Cathode-Ray Oscillographs, Cathode-Ray Tubes, Electronic Switch and associated electronic equipment, contained in Catalog B. Copy sent on request written on your business letterhead.

DUMONT
ALLEN B. DU MONT
LABORATORIES, Inc.
Passaic ★ New Jersey

New Products

(Continued from page 18)

tional Schering bridge, the equipment includes a voltage amplifier, phase selectors, thyratron circuits and motors, and recorders. The amplifier increases the feeble signal appearing at the output of the bridge when unbalance occurs, so that sufficient voltage is available to operate the phase-selector circuits. The phase selectors separate the voltage components of bridge unbalance produced by specimen changes. These components cause the proper thyratron to supply power to motors which rebalance the bridge. Two recorders follow the position of the balancing elements in the Schering bridge, recording capacitance and power factor of the specimen. Chart speeds of one inch per minute and one inch per hour are provided.

Ignition Marker.—An improved ignition marker, suitable for aircraft engines and many other applications, has been perfected by the Irvington Varnish & Insulator Co., 24 Argyle Terrace, Irvington, N. J. The markers consist of lengths of inside and out varnish-impregnated insulating tubing, on

which suitable identification is screen printed with a specially formulated ink. The marker is furnished in standardized lengths which are slipped over the wires to be identified. The new markers are available in two diameters (nominal I.D. .263- or .294-inch) with either of two heights of symbols, and in two standard lengths.

Recording Thermometers.—The Bristol Co., Waterbury, Conn., has developed two new recording thermometers of the liquid filled type, known as the case-compensated class I recording thermometer and the fully-compensated class I recording thermometer. Improved design and construction of the measuring elements, tubing, and bulbs in these instruments extend the field of application of the liquid filled thermometer, making it possible to take advantage of the desirable characteristics of the Class I thermometer system on a greater variety of temperature-measuring problems. The case-compensated instrument is offered in temperature ranges up to 400 degrees Fahrenheit and tubing lengths up to 10 feet or longer, depending on conditions surrounding the installation.

Three-Pole Relay.—G-M Laboratories, Inc., Chicago, Ill., have added a 3-pole relay to their line of type C relays. One of the primary features of the type C relays is the self-cleaning, wiping action of the contacts. Each time the contacts close, one contact is drawn a small distance across the other, thus operating to displace dust particles and to wear through films of corrosion, if any. Machine assembly of parts is another feature, influencing economical production. Additional features include long mechanical and electrical life and reliable operation. Available for a large variety of operating voltages, either direct or alternating current, these relays can also be had with any of a number of contact materials to suit individual applications.

TWO INSTRUMENTS
EVERY
LABORATORY NEEDS

The Acme Insulation Breakdown tester not only indicates grounds, shorts or opens but provides for the checking of circuits at approved voltage standards (double the rated voltage plus 1000). Manually adjusted with secondary voltage rating of 500, 1000, 1250, 1500, 1750, 2000 and 2500 volts. Portable and designed with every safety factor.

The Acme Voltrol (made in portable and panel mounting types) gives complete manual control over line voltage in stepless range from 0 to 135 volts. Not a resistance type regulator, output voltage is independent of load.

Acme also manufactures Luminous Tube Transformers, Fluorescent Lamp Ballasts, Radio and Television Transformers, Mercury Vapor Lighting Transformers, Air-Cooled Power Transformers.

THE ACME ELECTRIC & MFG. CO.
22 Water Street • Cuba, N. Y.

Acme Electric
TRANSFORMERS

Long Term INSURANCE

against production bottlenecks . . . high maintenance!

Here are three WESTON Instruments that provide the dependability, the broad utility and the time-saving facility *essential* for successfully battling today's production bottlenecks . . . keeping crowded production lines rolling smoothly and efficiently. But like all WESTON Instruments they are designed and built with an eye on *your* future . . . built to give the "long-term" dependability which stems from WESTON design and manufacture. Thus they will *protect* you during this active defense period . . . and their protection against inefficient operations and high costs will remain in "full force" long after the defense period has passed. Literature gladly sent on request. Weston Electrical Instrument Corporation, 664 Frelinghuysen Avenue, Newark, New Jersey.

WESTON *Instruments*

The WESTON (Model 633) AC Clamp-Ammeter

Provides the *quickest, simplest* means for testing electrified equipment *regularly* . . . thus insuring efficient, uninterrupted operations . . . forestalling costly power leaks, or breakdowns. The clamping jaws are simply closed over the conductor or busbar, and current reading taken. Circuits are never disturbed . . . work never interrupted. A big time and money-saver in any shop. Has 6 current ranges for maintenance needs.

The WESTON (Model 703) Foot-Candle Meter

Measures fluorescent, mercury-vapor, incandescent and all other types of lighting *direct* . . . without correction factors. Equipped with the WESTON VISCOR filter . . . a stable, all-glass filter which corrects for all types of lighting regardless of color composition. Saves time, eliminates errors in testing. Available in models for shop and laboratory requirements.

The WESTON (Model 785) Industrial Circuit Tester

With 27 carefully selected voltage, current and resistance ranges, Model 785 handles "trouble" in the most efficient, practical manner. With DC voltage sensitivity of 20,000 ohms per volt, it is ideal for testing sensitive relay circuits, signal and telegraphic systems, photocell circuits, alarm systems, etc., etc. . . . also for testing small motors and controls, lighting circuits, etc., etc. Can also be used with current transformers and voltage multipliers.

VARNISHED CAMBRIC • RUBBER COVERED POWER CABLES • BUILDING WIRE

• SERVICE ENTRANCE CABLE • MAGNET WIRE •

SIGNAL CABLE • FLEXIBLE CORDS • ARMORED CABLE

CRESCENT ENDURITE CABLES

FOR LIGHT AND POWER

Type RH and RHL
Meet Federal
Specifications JC-106-A,
JC-121

CRESCENT makes all types of cables to meet every requirement.

CRESCENT INSULATED WIRE & CABLE CO.

• RUBBER POWER CABLES • VARNISHED CAMBRIC CABLES

• BUILDING WIRE & CABLE • CONTROL CABLES

• PARKWAY CABLES • PORTABLE CABLES

CRESCENT
WIRE and CABLE
Factory: TRENTON, N. J.—Stocks in Principal Cities

CRESCENT ENDURITE SUPER-AGING INSULATION • WEATHER-PROOF WIRE

Perfect INSULATING COMPOUNDS for a wide range of temperature

In the Northern States, on the Gulf Coast, and both east and west—Minerallac Insulating Compounds are specified . . . proving that these materials do "stand up" no matter what change in temperature may arise.

• WRITE FOR BULLETIN 186 •

MINERALLAC ELECTRIC CO.
23 NORTH PEORIA ST. CHICAGO

ROWAN
Oil Immersed
CONTROL

BY USERS EVERYWHERE

ROWAN CONTROL
THE ROWAN CONTROLLER CO., BALTIMORE, MD.

"NEVER SAW A CABLE TAKE PUNISHMENT LIKE AMERCLAD!"

ENGINEERS familiar with Amerclad find it hard to believe that anything made of rubber could be so tough. They've seen it dragged day after day through stony open-pit mines, run over by loaded mine cars, or exposed to water and grease and general machine-shop abuse. Yet it stubbornly resists damage, goes right on delivering power as though nothing had happened.

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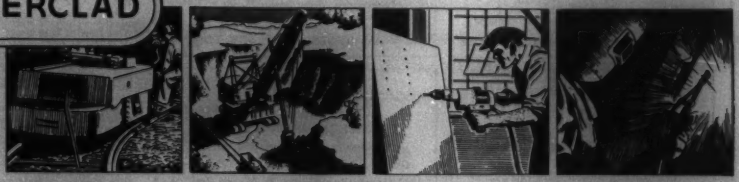

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A weekly bulletin of engineering positions open is available to members of the co-operating societies at a subscription of $3 per quarter or $10 per annum, payable in advance.

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REGISTERED PROF ENGR; 28 yrs exper des, constr, pwr houses, substations, indus plants. Exec engr large util; purchased engg eqpt foreign interest. Available short notice. E-803.

DESIGNER, E.E.; 37, married; good exper layout elec test eqpt and accessories, motors, transf, radio apparatus; also some supervision. Strongly interested in elec product devpmt, des, scheduling. Location, Greater New York. E-804.

TECHNICAL GRAD; 42, family man; 14 yrs present firm, wishes permanent change factory production. Handled up to 200 men, various machines and other details of production. Moderate salary. E-805.

S.M.E.E., M.I.T., 1933; 30, single; 7 yrs with pneumatic tool and machinery mfr, application elec and electronic methods to des problems and special tests, devpmt testg machines. Prefer East. E-806.

B. of E.E., Polytechnic Inst of Brooklyn, 1938; 33, now employed. Desires pos with future in E.E. with mfr or organization providing E.E. services. Location, New York City or vicinity. E-807.

B.S.E.E., Univ of Kansas, 1940; 24, married; hard of hearing. Wants permanent pos in des, estimating, draftg, with chance for future. Employed. Location not important, prefer Midwest. E-808-742-Chicago.

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B.S.E.E., Ph.D. in Physics; 32, married; 2 yrs plus 3 summers industry. 5 yrs Instructor and Asst Prof of Elec Engg. Desires teaching, devpmt or research pos. Any location. E-812.

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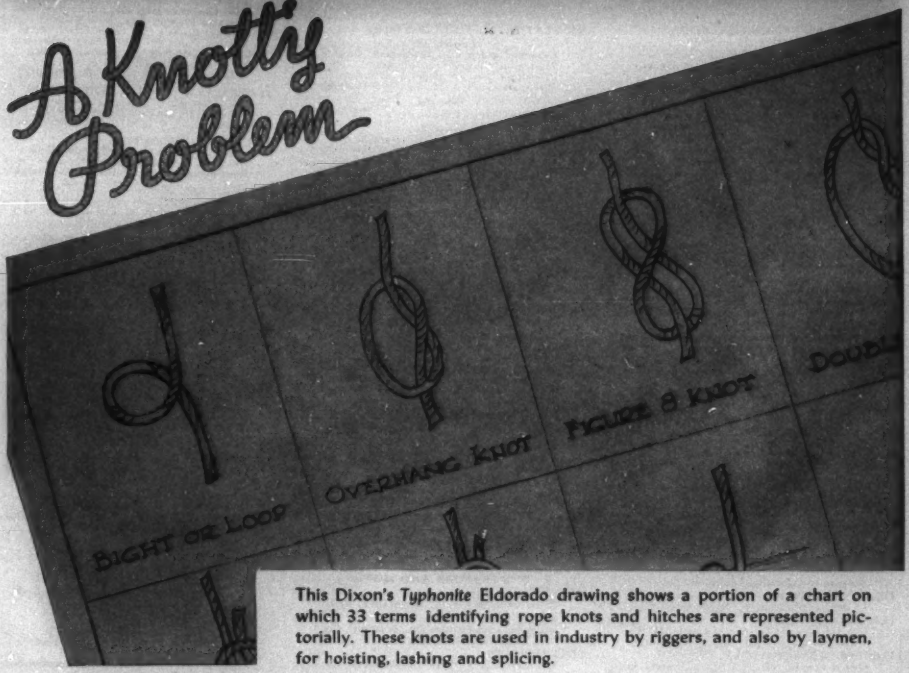
TYPHONITE ELDORADO PENCIL PAGE

A Knotty Problem



This Dixon's *Typhonite* Eldorado drawing shows a portion of a chart on which 33 terms identifying rope knots and hitches are represented pictorially. These knots are used in industry by riggers, and also by laymen, for hoisting, lashing and splicing.

In making these drawings a Dixon's *Typhonite* Eldorado 2H was used—an identical twin of every other *Typhonite* Eldorado 2H. A *Typhonite* Eldorado stamped "2H" is always a 2H—everywhere.

Such startling uniformity throughout the entire range of 17 degrees is possible only because the leads are made from *Typhonite*. *Typhonite* is a new form of graphite whose particles are minute twins. Each particle is minute in size and each is the same size. And the size is controlled to that found best for lead making.

To create matchless *Typhonite*, natural graphite is battered against itself in a typhoon of super-heated steam until the new form, *Typhonite*, emerges. The *Typhonite* process is exclusive with Dixon.

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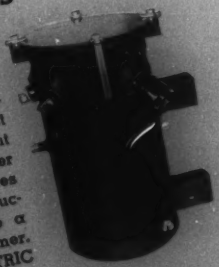
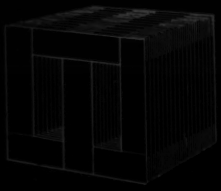
Kuhlman's

BENT-IRON CORE—AVAILABLE SINCE 1935—THE GREATEST IMPROVEMENT IN TRANSFORMER DESIGN IN FIFTY YEARS

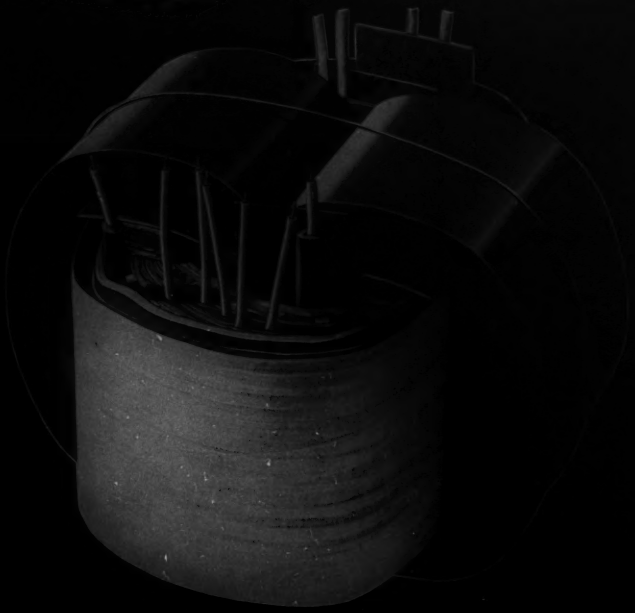


Conceived, designed and produced, by Kuhlman in 1933, the Bent-Iron core has proved to be a remarkable development in transformer design. This new type core assures fluxing parallel to the rolling direction of the steel thus utilizing to the fullest extent the many advantages inherent in present day magnetic materials. Permeability is higher and hysteresis is lower than in identical cores fluxed across the grain. In addition, this construction reduces reluctance and makes possible a lighter, smaller, more easily handled transformer. For further facts write to KUHLMAN ELECTRIC COMPANY, BAY CITY, MICHIGAN.



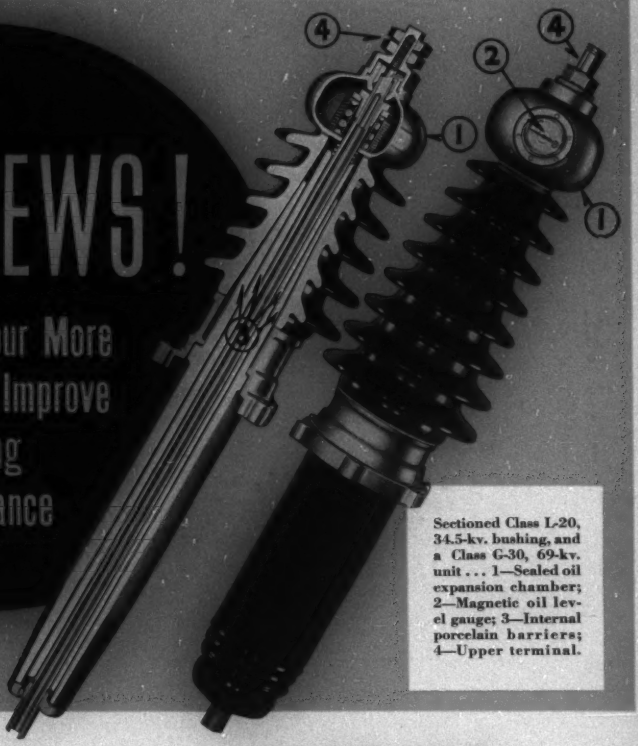
A conventional core which has several joints of appreciable flux densities and in which much of the magnetic material is fluxed against the grain.

A B I core with the magnetic material fluxed parallel to the grain, thereby reducing both circuit reluctance and exciting current and greatly increasing space factor.



BIG NEWS!

O-B Adds Four More Features to Improve Bushing Performance



Sectioned Class L-20, 34.5-kv. bushing, and a Class G-30, 69-kv. unit . . . 1—Sealed oil expansion chamber; 2—Magnetic oil level gauge; 3—Internal porcelain barriers; 4—Upper terminal.

1 COMPLETE SEALING

New oil expansion chamber *on all sizes* prevents breathing of moisture-laden air which might reduce insulating value of oil . . Maintains electrical stability, the sealing being permanent . . Permits bushings to be stored or handled in any position without oil loss . . Eliminates need for adding oil at any time.

2 MAGNETIC OIL GAUGE

Provides oil level indicator for all Class G bushings which can be read easily from considerable distance . . Maintains readability since oil cannot reach and discolor the dial . . Eliminates possible gauge glass oil leaks.

3 MORE INTERNAL PORCELAIN

Improves over-all electrical efficiency . . Adds to the dielectric stability since porcelain is unaffected by temperature, condition of oil, electrical stress or time . . Increases safety factor against puncture and internal over-surface stress . . Permits a better electrical grading, insuring absence of radio-disturbing corona.

4 INTERCHANGEABLE TERMINALS

Make each transformer bushing suitable for many terminal combinations, reducing number of bushings in stock . . Allow draw cable or fixed conductor connections to be made or rearranged without disturbing the oil seal.

Buy the Best ... Buy O-B

Ohio Brass (B)

MANSFIELD, OHIO, U. S. A.

Canadian Ohio Brass Co., Ltd., Niagara Falls, Ontario